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Modification of the Lid-Reflex by Voluntarily Induced Sets

By

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Yale University
March, 1931.

HELEN PEAK.

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INTRODUCTION¹

The importance of 'set' has long been recognized in the psychology of the higher thought processes, and terms such as 'Aufgabe', 'Determining Tendencies', and 'Einstellung' call to mind the Würzburg experimentation and controversy which eventuated principally in the demonstration that the problem with which the observer started his introspection had a great deal to do with the subsequent course of his thought, a fact which was not wholly new, to be sure, but which had never been so clearly enunciated. Somewhat analogous observations have been made from time to time in regard to the less complex processes in the organism. Lombard (30), Jendrassik (25), and others noted early that voluntary activity of one sort or another had an augmentatory effect on the knee jerk, and an increasing amount of evidence is becoming available which indicates that the total condition of the organism prior to, and simultaneous with, stimulation of any specific nature has its effect on the response and must be considered, even when the response is a so-called reflex.

Despite the recognized importance of this whole field of evidence, many studies both from psychological and physiological laboratories have totally neglected the facts and have rather consistently overlooked certain features of the pre-stimulus situation which in the intact organism should be taken into account. This is particularly true of the more psychological factors. These are, of course, notoriously difficult to control and nothing approaching a satisfactory technique for handling the problem is available. There are, however, certain crude controls, such as carefully planned and administered instructions and introspective checks which appear to be superior to the complete neglect of the problem, for it is safe to assume that some sort of a set toward an experimental situation is always established, even when uncontrolled.

¹ This monograph contains the major portion of a dissertation presented for the Degree of Doctor of Philosophy in Yale University, 1930.

In contemplating a series of researches on the lid-reflex, the determination of the effect of such sets, when induced by definite instructions, appeared to be logically prior to certain other investigations. The present study has attacked a very limited aspect of the question but it affords evidence which makes clear the magnitude of the problem in regard to this particular bit of behavior and suggests a wide field for experimentation.

It should be clear that the term 'set' is employed here in a very broad sense, referring to the general condition of the organism when a specified stimulus is presented. Obviously, numerous factors determine this general condition, so that control of the instructions takes into account only one of many variables. Nevertheless, by means of the usual experimental procedure of varying a single factor systematically on a background of general and unsystematic change, it should be possible to observe how this factor is related to resulting phenomena. It is impossible from our present controls to describe what conditions the instructions produced in the subjects and we shall imply nothing by the use of the term 'set' as to special types of mental content or physiological condition. A thorough-going experiment should provide objective checks and measures of the immediate effects of instructions, as well as control of the instructions themselves. In the absence of data from such sources, however, it is justifiable to correlate change in instruction with modification of reaction without reference to the intervening links in the sequence.

In the present experiment, then, the lid-reflex in response to a sudden noise was elicited on the background of sets established by three different kinds of simple instruction, well known in psychological procedure, and the extent and direction of modification of the reflex were recorded. Specifically, we have examined the effect of such pre-stimulus conditions on: (1) the amplitude of response; (2) the latency of response; (3) the variability of response; and (4) the integration of the response, as indicated by the shape of the curve which the eyelid describes as it closes and opens. The three sets have been called *Relaxation*, *Lid-Voluntary*, and *Finger-Voluntary*. The relaxation set is essentially a passive

state in which the subject is requested to relax and become as limp as possible. The lid-voluntary involves what has been termed traditionally, a 'muscular reaction'. The subject is instructed to wink the eyes voluntarily as quickly as possible in response to a loud noise, with attention focused on the movement of response. Here the reaction usually consists of two responses (important exceptions to be noted hereafter): first the lid-reflex at short latency, and secondly a voluntary response of the lid at a longer latency, both responses having the same stimulus. (See Figure VI, No. 1, p. 21). Similarly, the finger-voluntary consists of a set to press a telegraph key with the index finger as quickly as possible with attention on the response movement. In this case, also, the stimulus for the lid-reflex is the same loud noise to which the subject has been instructed to react with his finger.

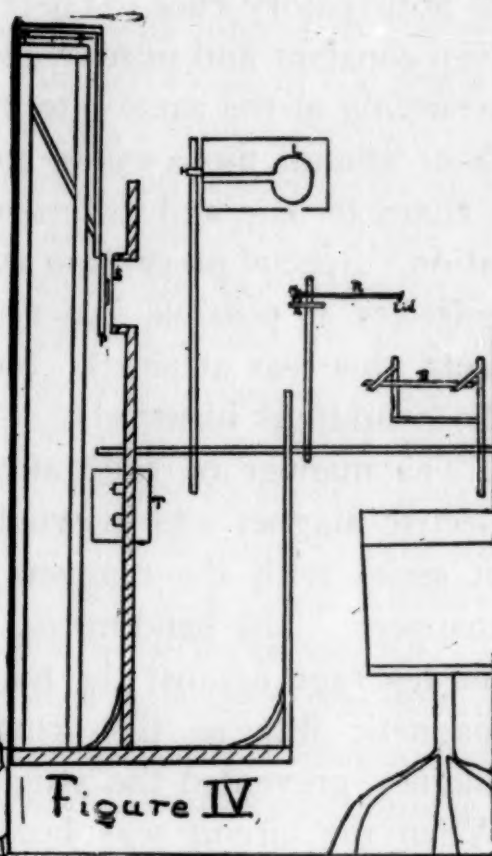
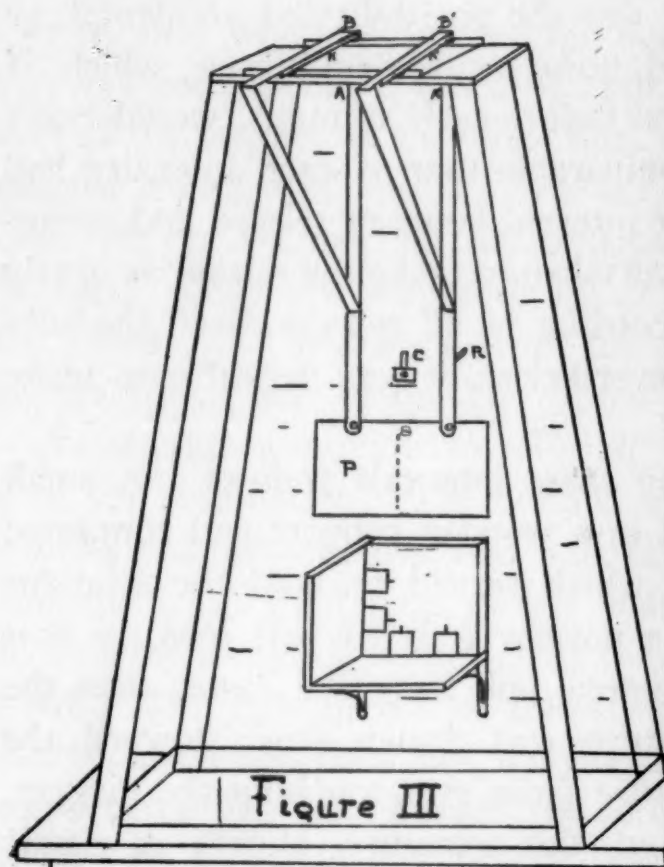
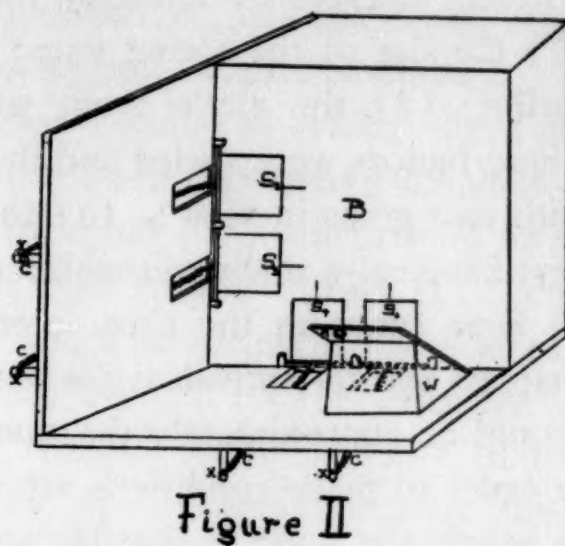
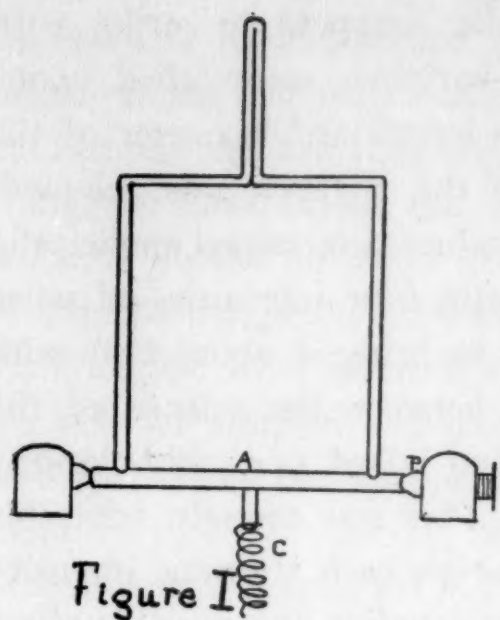
Throughout the experiment four intensities of noise were used. The order and experimental setting were the same for all three sets. The portion of the results related to the effect of intensity of stimulation will not be discussed in the present paper.

I. THE APPARATUS

The apparatus was designed to record photographically the response of the eyelid to auditory stimulation of four different intensities so that readings of the latency, the time to maximum response, the amplitude, the form of the response, and time of recovery might be made. The essential features of the apparatus follow: (1) The stimulation device consists of a series of four spring snappers of different tensions and excursions, which strike on a sounding board and produce four different intensities of noise. (This is a modification of the Dodge mouse trap.) (2) The moment and the intensity of stimulation are registered photographically by means of a microphone and Dodge telephone recorder. (3) The response system consists of a light lever, one end of which rests on the eyelid, while the other carries, over its axis, a concave mirror, reflecting a beam of light which moves with the movement of the lid. (4) A vibrating time marker casts a shadow on the photographic paper. (5) A moving plate, carrying photographic paper, passes behind the slit which admits the lights and shadows to be recorded on the sensitive paper. The plate swings on double pendula.

1. THE STIMULATION DEVICE

The snappers (Fig. I, II). Four snappers (S_1, S_2, S_3, S_4) are constructed so that they strike upon the same sounding board, (B), an 8 inch square of white pine forming the side of an open box. These snappers are made of $\frac{3}{16}$ inch tool steel, bent to form rectangular loops, $1\frac{3}{4} \times 2$ inches, each of the same size. Each of these loops is mounted on a rod of $\frac{3}{8}$ inch tool steel, which forms the axis (A) and turns on point bearings (P). Coiled wire springs (C) are attached at right angles to the axes at their centers. These springs pass through openings in the base on which the axes rest and are secured to the bottom side of the



base by adjustable screws (X), which make possible adjusting and fixing permanently the tension on the different springs. Two of the snappers have as a common base (Fig. II) a continuation of one of the vertical sides of the sounding box; both bases are perpendicular to the sounding board.

Intensities. In order to cause the snappers to strike with different degrees of intensity three variables were relied upon: (1) the size of the spring wire; (2) length and diameter of the spring; (3) the angle from which the snapper was released. These factors were varied and their values determined empirically with two goals in view: (a) to obtain four intensities of noise psychologically distinguishable; (b) to bring it about that with all four snappers the time interval between the release of the snapper and its arrival at the sounding board (*i.e.*, stimulation) should be approximately the same. This was thought advisable in order to make conditions attendant on each stimulus intensity as nearly the same as possible and to equalize any possible effect of anticipatory cues. There was the possibility of accidental, or even constant and unrecorded, noise incident on release, which, if occurring at the same interval before each stimulus, would make those stimuli more easily comparable than if each intensity had a characteristic and different interval between release and stimulation. Special precaution was taken to make the release as nearly noiseless as possible and according to all reports from the subjects, this was attained. Nevertheless, it was desirable to make the conditions identical.

The manner of calibrating these intervals follows. A small electric magnet was inserted in a wooden support and connected in series with the magnets which served to hold the stimulus snappers. The bending of a narrow strip of soft iron, so that the leverage against the magnetic pull increased faster than the magnetic flux as the armature was drawn down toward the magnet, prevented the armature from ever touching the magnet. When the circuit was broken, the armature, always in elastic equilibrium, moved up quickly, thus indicating the moment of release of the snappers. Any change in current caused a movement of the armature, and there was not the usual lag due to residual magnetism. The armature cast a shadow across the photographic slit. By means of this device it was possible to ascertain the moment of release of the snappers and by means of the device for registering the stimulus (to be described) to find

the moment of stimulation. From these values the interval between release and snap was easily calculated, and the equation of the interval for the four different stimuli became possible.

Having determined the necessary angle at which the four snappers should be set in order to obtain the desired intensities, permanent wedge-shaped blocks of wood (W) constructed to fit these angles, were inserted under each snapper (Fig. II). For the sake of simplicity only one wedge is pictured. The angles through which the snappers move are 24.5° for intensity A (smallest); 24.0° for B; 68.5° for C; 90.0° for D. In the wedges small magnets (M) were inserted approximately flush with the upper surfaces. A light strip of iron, encased in rubber tubing, save where it touched the magnet, was hinged to a post, and extended across the end of each snapper to form the armature of the magnet on the other side. When a circuit through the magnet is broken, this small lever is quickly and noiselessly thrown clear of the snapper by the tension, and thus the snapper is released. Only one snapper is set at a time, and the other three, not in use, are held back from the sounding board by wooden latches which may be quickly turned across the snapper loops.

An attempt was made to calibrate the intensities of the noises used for stimulation. The method was subject to errors, which will be enumerated, but was adequate for determining relative intensities. A light pine stick 3 inches long was glued securely against the sounding board, at its center and perpendicular to the board. Through the end of this stick was fastened a silk thread which passed around a steel spindle, 0.33 inches in diameter, and was secured to a post beyond the spindle. The stick, the spindle, and the post were in one straight line perpendicular to the sounding board. The spindle turned on highly polished points with little friction. Upon the spindle was fastened a concave mirror, reflecting a beam of light to a recording camera with slowly moving film. When the snapper struck, the sounding board as a diaphragm began vibrating and these vibrations were transmitted by the stick to the thread which caused the spindle to turn, carrying the mirror. The mirror was deflected in proportion to the displacement of the diaphragm. Ten readings, taken under

identical conditions, showed average deflections on the film of 4.7 mm., 12 mm., 26.5 mm., 47.1 mm. for the four intensities.

The following possible sources of error in this method of calibration of intensity should be mentioned:

(1) An attempt was made to place the stick on the sounding board in an absolutely perpendicular position, but there is the possibility of a slight error having been made, which would cause a loss of recorded movement of the diaphragm proportional to the obliquity of the angle from perpendicular. This should be a negligible constant for all intensities.

(2) Some tension on the string passing from the diaphragm around the spindle was necessary. This may have slightly deformed the diaphragm prior to its being struck. This again would effect only absolute values and those but little.

(3) There is the further possibility that the thread slipped on the spindle, though it was tight and the spindle moved with very little friction. Pulley 'dope' was used on the thread, and aided in preventing any slipping.

(4) The impact was measured from the center of the diaphragm which was in no case the point of impact, as the snappers all hit in different places. It was approximately equidistant from the four snappers, however, so that the error introduced here would apply to the absolute and not to relative intensities.

(5) An attempt was made to make the beam of light from the mirror strike the film perpendicularly. This was done in order that we might correct for the error arising from the fact that the film forms a tangent to the arc formed by the perpendicular distance from the mirror to the film, so that the distance from mirror to film is greater as the distance from the point of tangency increases. This means that the optical magnification of throw of the diaphragm would be greater for the intensities which caused a greater throw of the mirror from its initial position. With the distances used and the deflection involved the error proved to be much below the error of measurement.

(6) Finally, the spindle and the beam of light reflected by the

mirror should move in a perfectly horizontal plane as the spindle swings from right to left. It was not possible to insure this absolutely with available instruments. With the distances involved, this would not be a measurable error.

These possible sources of error were too small to cause significant errors in the records of relative intensities of the stimulus noises. A later report on the effect of intensity will be concerned only with these relative values.

2. RECORDING THE MOMENT OF STIMULATION

A receiver recorder¹ registers the incidence and relative amount of noise. Immediately in front of the sounding board, but not touching it, a telephone transmitter is placed. This is in series with three dry cells and an ear phone of a radio head-piece. Across the aperture in the ear phone a twisted silk thread is stretched, and to it is fastened a small concave mirror mounted on a delicate aluminum base. An offset on the aluminum base rests on the diaphragm of the telephonic receiver and is held against it by the tension of the twisted thread, so that any vibration of the diaphragm deflects the mirror, which turns on the thread as an axis. With the thread running horizontally, a beam of light, reflected from the mirror, moves vertically. When the snappers hit the sounding board, the resistance change in the transmitter causes a movement of the diaphragm which is registered by the beam of light reflected from the mirror through the slit to the moving film. This shows on the record as a sharp upward shift in the line and is easily readable for time of incidence and amplitude. Although there are differences in the amplitude of the throw with differences in intensity of the noise, the relation between the two is probably not exactly proportional owing to physical characteristics of the transmitter.

3. RESPONSE RECORDERS

a. *The response of the lid.* The subject is seated in an adjustable desk chair with the open end of the box sounding board

¹ This recorder was devised by Professor Raymond Dodge and is first described here.

slightly behind him and 20 inches to his left. A small red cross five feet in front of him serves as a fixation point. The subject's head is inclined backward slightly off the vertical position and rests against a support at the back. (See Fig. IV which shows response recorder and cross section of moving plate.) Vertical movement of the head is prevented by means of a biting board (B) which consists of a thin wooden strip, a 'tongue depressor', fastened in a frame which is adjustable in height and angle. The angle of the chair, the head rest and the biting board are kept constant from session to session. When the subject has been comfortably adjusted in the apparatus, a small wooden lever (R), 2 mm. in diameter and 22.3 cm. long, wrapped at the distal end with adhesive tape, is pressed gently upon his left eyelid directly above the eye lashes until it adheres. The other end of the lever rests on an axis (A) and carries a small concave mirror (M) which reflects a beam of light from a 200 watt lamp (L) placed directly above it. This beam is reflected through a slit on to the sensitive paper which moves behind the slit (S), 38 cm. from the mirror. As an axis a small pin through the lever turns with little friction on V-shaped bearings of tin plate. As the eyelid moves down, the mirror on the axis turns upward and the beam of light is deflected vertically in direct proportion to the extent of the lid movement. At the distances stated, the proportion of lid movement to vertical distance on the record is 1: 3.404, so that the exact amplitude of the lid movement can be calculated. We have not, however, reduced the measurements from our records to absolute values.

b. *The finger response.* In one portion of the experiment a device for recording the time of response of the finger was required. For this purpose a telegraph key was placed in circuit with the telephone receiver recorder, used for registering the moment of stimulation. The circuit remained closed until the subject pressed the key and then the beam of light was deflected sharply upward. This response usually occurred following the stimulus and was easily distinguishable from the deflection caused by the stimulus by its far greater extent. On the few

occasions when there was an anticipatory response shortly before the stimulus, the stimulus found the circuit open and so was not recorded.

4. TIME

A plane mirror, reflecting light from the same lamp used for the concave recording mirrors, shadows the vibrating armature of a double magnet in circuit with a 100 D.V. König tuning fork and gives a shadow record of time on the same record with the stimulus and response lines. The time from crest to crest of the line represents 10 sigma. This same "wash" of light from the plane mirror is interrupted by fine silk threads passing horizontally across the slit at distances 1 mm. apart. These give shadow lines on the record by which the amplitude of the response may be easily and quickly read. They also make it possible to determine accurately just when the response line starts away from the position of rest. The time marker is practically noiseless being suspended on elastic bands.

5. THE MOVING PLATE

By means of the device now to be described the movements of the light beams and shadows cast by the stimulus recorder, the response mechanism, and the time line, are recorded on sensitive photographic paper which moves behind the slit (S) letting through the light. (See Fig. III.) The device is essentially a modification of the Dodge pendulum photochronograph. The plate (P) carrying a pack of sensitive papers, 7 x 2½ inches, is suspended on two wooden pendula (A and A¹), 28 inches long. The pendula are attached to light wooden cross beams (B, B₁) to which are screwed tin-plate knife edges (K). These axes turn on tin V-shaped knife edge joints set at right angles to the cross beams. The bearings are relatively frictionless and completely noiseless. The fact that the plate is fastened to two pendula brings it about that it remains in a horizontal position as it moves along, only altering its height; *i.e.*, it falls as the pendula approach a vertical position and rises in moving off from this point in either direction, so that the beam or shadow

at rest is shown as an arc on the record, although horizontal distance may be read in straight lines instead of arcs. The plate is started from its extreme position on the left where it is held by a stop. Release is by hand since that proved to be by far the most noiseless method. When the plate moves at the rate determined by its own weight and the distance of fall, it traverses about 0.7 mm. per sigma at the center of swing. It may be speeded up to move very much faster by attaching a rubber band at the right end of the swinging system, stretching it to the right, thus pulling the plate over more rapidly. The fact that there is a small amount of acceleration causes no difficulty, since the rate of any interval on the record can be determined by the precisely simultaneous time line. All movements of the apparatus and the experimenter are screened from the subject.

A small rod (R), covered with sponge rubber, extends out from the right hand pendulum, and, when it reaches a certain point, hits a contact rod (C) and breaks the circuit through the magnets which hold the stimulus snappers in place. This guarantees the occurrence of stimulation at the appropriate time so that the stimulus and response are recorded as the sensitive paper passes the slit.

6. THE RECORD

In the records of Fig. V, p. 20, the following features may be noticed: (1) At the top of the record is the time line, the distance from crest to crest representing 10 sigma. (2) Next is the stimulus line. The upward movement of this line indicates the moment of stimulation. Near the end of the record another, larger shift in the line shows the moment of the finger reaction. (The presence of two parallel lines is caused by the curved filament in the lamp.) (3) The lid response line is the dark line at the bottom of the record. As long as this line follows one of the white abscissae the lid is motionless. The shift from this position indicates movement. When the shift is upward, the lid has moved down in the direction of closure; when the line moves down, the lid is opening.

The reading of amplitude from these records involves simply

a counting of the number of abscissae crossed from the position of rest to the point of maximum closure. Every fifth shadow is a heavier line so that counting is facilitated by making it possible to proceed in five millimeter steps. The reading of latency is more tedious. It is necessary to determine first the moment of beginning of the response, and this must be done with care as the initial rise is more or less gradual. Then the record is placed under parallel ruler guides whose distance apart may be adjusted by means of a micrometer screw. A base line determined by the angle at which the light from the slit meets the film is provided in the over-exposed strip at the end of the record. The parallel ruler guides are placed parallel with this black line, and are adjusted so that the left hand ruler crosses the point at which stimulation occurs and the right hand one crosses the point of beginning response. The distance between these two rulers is then marked off on the time line, and reading is direct from this line. This is a more accurate method than that which involves the assumption that a certain distance is equal to a certain amount of time at all points in the record, since it avoids any error due to acceleration of rate of movement of the record. Finally, the number of oscillations of the timer occurring between the indicated points is counted and interpolation is made for distances short of a complete oscillation. Here it was necessary to assume that one-tenth of each oscillation was equal to one sigma, but the error must be well within the error of measurement, for very little acceleration could occur within the short distance covered in ten sigma. On our records this distance is about six millimeters.

II. PROCEDURE

The experiment was conducted in a room from which light was excluded except that from the lamps used in the apparatus. This was constant. An attempt was made to avoid all noise, except that of the stimulus, but this was quite impossible as the room was not sound-proof. From time to time during the course of the experiment there were disturbing and uncontrollable noises. These extraneous disturbances varied about equally for the three sets, though they were apparently more annoying during relaxation.

The subjects, three women and two men, came regularly at the same hour of the day. The hour varied for different subjects, but all sessions were held during the afternoon.

On the first and second days subjects were given the following instructions, designed to orient them in the experiment:

GENERAL INSTRUCTIONS

This experiment is designed to study the effects of various sorts of mental and physical sets on the lid reflex. It will be the task of the subject to try his very best to carry out the instructions given him by the experimenter. It is most important, however, to realize that absolute frankness is necessary. Every one recognizes the difficulty of carrying out instructions and it is no reflection on the subject if he sometimes fails to do as instructed. At these times he should report the failure to the experimenter. Do not consider any observation or any unusual occurrence in the experiment too trivial to report. If you feel tired or uncertain or confused or distracted be sure to report the fact. You may throw important light on something the experimenter has not thought of.

When you come to the experiment each day be sure to report any unusual condition of your general health or emotions. All of these things are of the highest importance.

If for any reason you feel it especially irritating to participate in the experiment you should communicate this fact to the experimenter, for it might be desirable to postpone the sitting, or to use one set in preference to another on that occasion.

On all occasions try to be as objective as possible. If you are uncomfortable do not be afraid of delaying the experiment by reporting it, for you will probably save time by doing so. The experimenter will welcome any criticism or delay which seems advisable to the subject. Your total reaction to the

situation must be considered and if you are irritated or hurried or otherwise disturbed and do not report the fact, the whole experiment will amount to nothing.

SPECIFIC INSTRUCTIONS

At the proper time the specific instructions were presented. For the three sets these instructions were as follows:

Relaxation. I. In this part of the experiment your task is simple: The chief requirement consists in asking you to be sure that you are comfortable and relaxed. Let yourself go completely and become as limp as you can. Do not exert yourself in any way. Close your eyes between trials. Should any tensions develop be sure to report it to the experimenter. Otherwise do not engage in conversation.

II. The only other task is to fixate the light when I say 'fixate'. As you do this let yourself definitely relax, drooping your shoulders and relaxing the diaphragm. Pay no attention to the stimulus, just be comfortable.

Voluntary Wink. I. As usual report to the experimenter any unusual event in the experiment, whether it be your own set or reaction or some action of the experimenter or the apparatus. If your head moves be sure to report it.

II. When I say 'ready', (1) fixate the light steadily until after stimulation, and (2) direct your attention toward the movement of blinking your eyes voluntarily just as quickly as you can in response to the snap. You may possibly wink reflexly first, but pay no attention to the presence or absence of the reflex; be sure that you wink voluntarily just as quickly as you can and that you are thinking of the movement of winking. Remember speed is the important consideration.

III. After reaction report on your set, stating whether it was 'good', 'medium', or 'poor'. Do not judge this in terms of the apparent speed of your reaction but only in terms of whether you are making the maximum preparation during the pre-stimulus interval for a quick reaction; *i.e.*, whether any thing was occupying your attention other than the attempt to make every effort to wink your eyes just as quickly as possible.

Voluntary Finger Reaction. I. Remember that you are to report to the experimenter any unusual event in the experiment whether it be your own set or reaction, or some action of the experimenter or of the apparatus. If your head moves, be sure to report that.

II. When I say 'ready', fixate the light steadily until after stimulation, and (2) at the same time direct your attention toward the movement of pressing the key with your index finger just as quickly as you can in response to the snap. Make your forearm very tense in order to try to accomplish this quick reaction, and remember speed is important.

III. After reaction be sure to report on your set, stating whether it was 'good', 'medium', or 'poor'. Do not judge this in terms of the apparent speed of your reaction but only in terms of whether you were making the maximum preparation during the pre-stimulus period for a quick reaction; *i.e.*, whether anything else was in your mind in the period between the ready signal and the stimulus other than the thought that you were to make every effort to move your finger just as quickly as possible.

The experiments were designed so that each set would be used on twelve different days, two sets being used each day. This made the experiment last eighteen days for each subject. 24 trials were given under each set each day, making a total of 48 trials a day. It was further arranged, in order to control adaptation, that each set should come first and last in the day an equal number of times and that each should follow each of the other two an equal number of times. The same set was never given twice on the same day, and each set appeared twice in the first three days, the second three, the third, etc. The same cycle was used for all subjects, but each started at a different point in the cycle, so that no one set would always begin the experiment.

Each day the experiment proceeded in the following manner: A pneumograph was placed on the subject before he sat down. Then he was adjusted in the apparatus and the lever placed upon his lid. The written instructions were handed him. This preparation usually required about 5 minutes. When the relaxation set was to come first, 10 additional minutes of silence were given the subject in order to relax. Otherwise, the experiment began immediately. The experimenter gave the 'ready' signal, then two seconds later (as judged by a stop watch) released the plate which set off the stimulus some 50 sigma later. This two second interval was not absolutely constant from time to time but the procedure was the same from experiment to experiment and presumably the variation around the two second interval was approximately the same. In the relaxation set an attempt was made to stimulate the subject at about the end of the exhalation phase of breathing as observed from the pneumograph. In a preliminary observation an estimate was obtained of the average time of each subject's breathing phases, and the 'ready' signal was given so that the end of the two second interval would fall in the exhalation phase. It had been suggested that this was a more relaxed state than inhalation. The control was, however, rather crude and was used only in the hope of favoring relaxation as much as possible. After stimulation the subject reported, as

instructed, for the two voluntary sets; in the relaxation set he and the experimenter were silent save when some unusual event required reporting. The apparatus was immediately set for another trial which followed in 30 seconds. This interval was also determined by a stop watch and was approximately constant for all sets.

Stimulation continued for 24 trials. Then the biting strip was removed from the subject's mouth and an interval of 10 minutes followed without stimulation. During this time the subject reported on the preceding series. In cases where either of the voluntary sets was to follow, conversation continued until the end of the interval, so that the subject would not become drowsy. When relaxation was to come next, however, there was no conversation after the report was finished and the subject was permitted to begin the process of relaxation at once. In all cases, stimulation began again at the end of the 10 minute interval and occurred every 30 seconds for 24 more trials. The subject's report completed that day's experiment.

The order of the intensities was arranged so that each of the four intensities occurred six times during a set series, and so that each appeared once in each four trials. The order was varied so that no intensity followed itself. An attempt was made to make each intensity follow each other intensity the same number of times but this could not be arranged. The same order was used throughout. It was necessary from the point of view of the experiment on sets, to keep this arrangement the same in order to reduce the variables as much as possible.¹

It should be mentioned that previous to the series of experi-

¹ Order of Presentation of Intensities of Stimulation.

A—Small intensity B—2nd		C—3rd D—Largest			
Trial	Intensity	Trial	Intensity	Trial	Intensity
1	B	7	A	13	A
2	A	8	D	14	D
3	C	9	A	15	B
4	D	10	B	16	C
5	B	11	C	17	A
6	C	12	D	18	D
				19	B
				20	C
				21	B
				22	A
				23	C
				24	D

ments from which the data of this study were obtained, the experimenter had become thoroughly practiced in the routine of the experiment as described. Over 2,000 records had been obtained from five different subjects in preliminary exploration and none of these data are included. Certain subsequent radical modifications in apparatus and minor changes in procedure have made this advisable.

It might be well to state here that our subjects did not attain a degree of relaxation approaching that described by Jacobson (24). There was no long period of training such as he used, so that the term 'relaxation' is employed only in a relative sense, to indicate that under this set the subjects were more relaxed than under the other two where there were tasks to be done. Some subjects, particularly III, found it irritating to be told to fixate under this set, but in most cases this action seemed to become automatic, and on a few occasions subject I actually went to sleep and snored and had to be awakened by repeating the instruction to fixate. Subject II also frequently became very drowsy.

It should be stated further that nothing is implied as to the distinctness or similarity of reflex and voluntary behavior as the terms are used in this portion of the paper. The terms were employed to make clear to the subjects the fact that they should be conscious of trying to perform the acts as instructed and we have referred to the act which they were to 'cause' as the 'voluntary' and to the other, non-effortful response, as the 'reflex'. This does not mean that the 'voluntary' response always felt effortful, for, as a matter of fact, subjects often remarked that it 'got away from them' and 'felt like a reflex'. However, they were conscious in varying degrees of an effort to produce a wink for which they were responsible. Since our whole problem is concerned with the attempt to discover the effect of the state of the organism set up by such instructions on the unintentional, relatively quick response of the lid to a loud noise, we shall have occasion to refer again to this whole question of reflex and voluntary behavior.

III. THE EFFECT OF SET ON THE FORM OF RESPONSE

Inasmuch as the set appeared to have some effect on the form¹ of response, it became necessary at the very outset to consider the configuration of the lid record before a satisfactory treatment of the amplitude and time became possible. Even casual examination of the records revealed a variety of responses, which included various irregularities and disturbances of what appeared to be a more or less characteristic integration. This brought up the question of whether we should be justified in making a quantitative comparison of responses which were obviously different from a qualitative point of view.

The difficulty was first evident in responses such as No. 2, Figure V. This form of reaction occurred most often in the voluntary lid set, and for all subjects it appeared after some practice. The early records in this set took the form of the first three records in Figure VI, where there is a reflex followed at a distinct interval by a second reaction, the voluntary response to the same stimulus which produced the reflex. Gradually, however, the second response tended to creep forward in time, so that in all cases, sooner or later, the second seemed to combine with the first, judging by the fact that the 'combined' response (No. 4, Figure VI) had the latency of the first reaction (Nos. 1, 2, 3, Figure VI) and the configuration of the second; *i.e.*, the lid remained closed instead of opening promptly. In this event, it became im-

¹ We have referred to this change as a qualitative alteration in contrast to the modification of amplitude and time which have been classed as quantitative changes. This does not imply anything about the possibility of also treating these qualitative differences in a quantitative fashion ultimately. It is clear that certain other features of the response curves, such as duration of closure, bear quantitative analysis, even with the present technique. Since, however, the change in duration is itself a complex result of the action of antagonistic muscles, the alteration here referred to as a change in form, is probably most accurately stated in such qualitative terms until more information is available about the components.

possible to distinguish the amplitude of the first reaction from that of the second, while the time of the second was completely obscured in the combination. The question of just what has taken place in a reaction like this one, cannot be answered without further experiment.² From the present point of view, however, it seems clear that the inclusion of amplitudes from records like this would involve the neglect of a qualitative difference and would make the quantitative results quite misleading. In other words, it would seem useful to distinguish the effect of set on the amplitude of an established integration and its effect in altering this integration. This point will be discussed more fully later in this report.

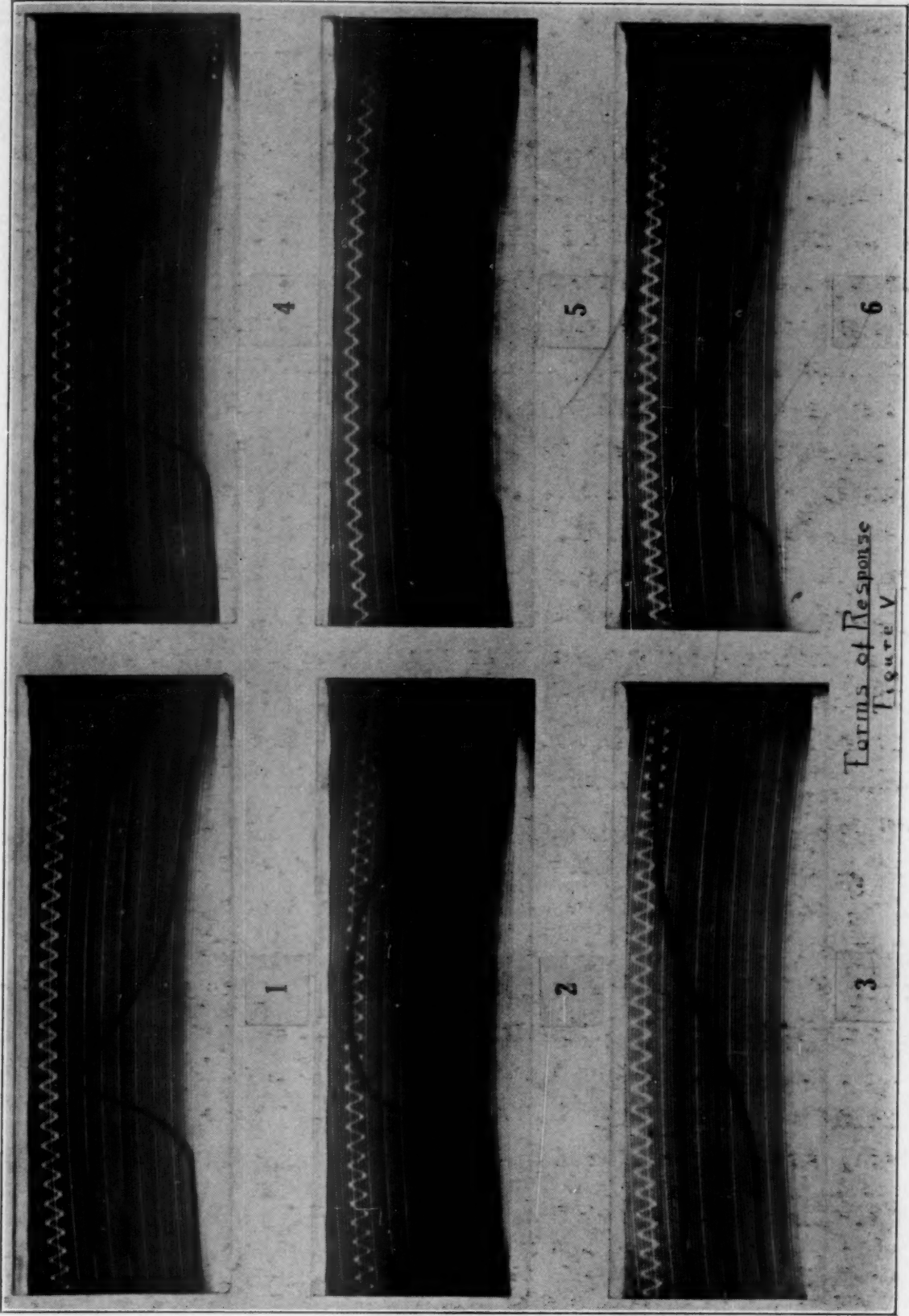
In addition to this particular case, there were other records which showed aberrations of one sort or another. Consequently, we decided to select responses as nearly homogeneous as possible and to eliminate all records with the following characteristics: (1) those with humps and irregularities on the upward or downward swing of the curve—Nos. 5 and 6, Figure V; (2) those which did not show a prompt opening of the lid following closure—Nos. 2, 3 and 4, Figure V; (3) those in which the response began before the stimulus was given; *i.e.*, anticipatory reactions. These were usually aberrant in form as well as in time.

Record No. 1, Figure V represents the general conformation and characteristics of the records selected for statistical treatment: (1) a smooth curve both on the upward and downward swing; (2) a latency from zero to 60σ ; (3) prompt opening of the lid after closure, so that the point of the curve is relatively sharp.³

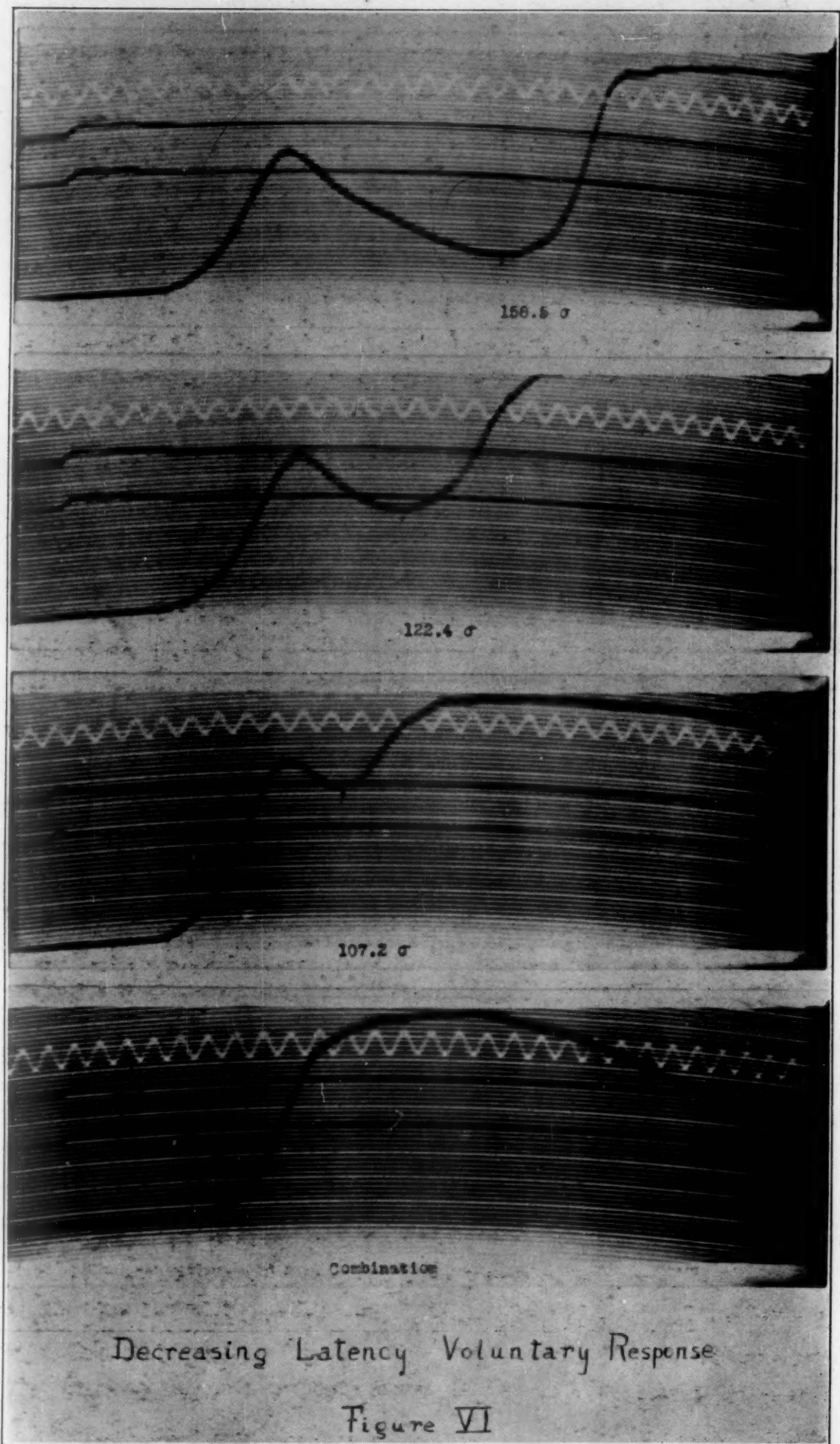
Table I reports the frequency of responses under three classifications: (1) Reflex Responses, those selected for the purpose

² It has been reported that this reaction occurred most frequently in the voluntary lid set; it was not, however, confined to this set but appeared frequently in the other two. It bears the look of conditioning, and would seem to be both a conditioned voluntary and a conditioned reflex, since it has certain characteristics of the voluntary and the unconditioned reflex!

³ There were some ambiguous cases where the decision of whether the opening was prompt was difficult. In case of doubt the records were excluded.



Forms of Response
Figure V



comparing the effect of the three sets on the amplitude of the reflex; *i.e.*, records like No. 1, Figure V; (2) Modified Reflexes, those eliminated because of their aberrant form—Nos. 2, 3, 4, 5, 6, Figure V; and (3) the anticipatory responses.

TABLE I
FREQUENCY OF RESPONSE BY CLASSIFICATION*

Subject	Set	Reflex† Responses No. 1	Modified Reflexes Nos. 2, 3, 4, 5, 6	Antici- patory	Total Eliminated
I	R†	232	42	11	53
	L†	88	189	18	207
	F†	176	99	14	113
II	R	154	106	17	123
	L	130	93	62	155
	F	96	132	59	191
III	R	92	139	11	150
	L	96	146	8	154
	F	143	82	7	89
IV	R	200	43¶	16	59
	L	221	6	4	10
	F	221	7	6	13
V	R	68	76	129	205
	L	74	80	131	211
	F	73	68	143	211
Totals by Sets	R	746	406	184	590
	L	609	514	223	737
	F	709	388	229	617

* The totals are not the same for all subjects because of elimination of records by accidental causes such as over-developing, light leaks, faulty adjustment of light beams, etc.

† See the discussion, p. 22, for meaning of 'reflex' here.

‡ In this table and in all that follow, R represents relaxation set, L the lid set, and F the finger set.

¶ It should be remarked that 35 of these modified responses were in the doubtful group; *i.e.*, the irregularities involved were small and usually consisted of a small rise on the downward swing of the curve as in No. 5, Figure V. This was the only case containing many of this type and their predominance here under relaxation makes one wonder if they should have been eliminated.

In terms of totals (Table I) the number of records eliminated is greater for each of the voluntary sets than for relaxation, so that the greater complication of form is correlated to a certain extent with the voluntary sets and may, not unreasonably, be considered as related in part to the superposition of voluntary reactions upon the reflex. This is more especially true of the lid-voluntary set. It may also be said, that, in general, the responses

under the relaxation set tend to resemble most frequently response No. 1, Figure V, while the other types of response are most frequent in voluntary sets.

In view of these facts, the classification and separate treatment of these responses is not only justified, but demanded, for there are several points of view from which the groups differ markedly. We summarize: (1) By definition the groups are different in form. Since the modified responses seem to bear a relation to the voluntary sets, it is thought that the complication of form may be due to the superposition of voluntary response on the reflex, in contrast to the type No. 1 response which under voluntary sets appears to be only augmented in amplitude, not altered in form. (2) The amplitude of the modified group of responses is clearly much larger than that of the type No. 1 response.⁴ (3) It will be shown later that the latent time is significantly different in the two groups. (4) We should mention the wholly practical fact that the point of maximum closure of some of the aberrant reactions was difficult of determination, which would have introduced a large error of judgment had these records been included. (5) Finally, the classification does not imply the establishment of this No. 1 response as the 'typical reflex'. It only sets it up as the most consistent, frequent and homogeneous response at short latency, which was obtained under the conditions of the experiment, and the one most clearly comparable from set to set in quantitative terms.

⁴ Here it should be pointed out that the elimination of the group of modified responses has definitely reduced the magnitude of the difference in amplitude of the reflex under relaxation and voluntary sets, since more of the large complex responses have been eliminated from the voluntary than from the relaxation set. Consequently, this procedure of classification has not changed the direction of the difference but has only diminished it. See Chapter IV for these differences in amplitude between sets.

IV. THE RELATION BETWEEN SETS AND THE AMPLITUDE OF RESPONSE

The statement has already been made in Chapter III that the amplitude of the lid-reflex is larger under voluntary sets than under the relaxation set. The present chapter reports the evidence for this statement and the added qualifications which are necessary. We are dealing now only with the relatively homogeneous group of selected records represented by record No. 1, Figure V. Stated briefly, this chapter will contain: (1) evidence for the larger amplitude of the reflex under voluntary sets as indicated by the frequency distribution of amplitudes, and by the measures of central tendency and overlapping, when responses to the same intensities of stimulation in each set are compared; (2) the relation of amplitudes of the reflex under different sets in the various stages of practice. This will introduce some exceptions to the first statement.

DISTRIBUTION CURVES

In the construction of these curves, all the amplitude values within each set were assembled and distributed in eight group intervals ranging from 0 to 48 mm.¹ The curves indicate the percentage of cases falling in each interval. The curve including

¹ This involves the error of throwing together responses to all four intensities of stimulation. Since the number of selected cases for each intensity is not the same, and since for most subjects, the relative number of selected No. 1 responses to large intensities is greater for the relaxation set than for the voluntary sets, it follows that the relative number of large amplitudes in the relaxation distribution is increased merely by virtue of this intensity factor. The error cannot be very large, however, for the differences in the number of cases is small. Further, the error must tend to reduce the number of large amplitudes in the voluntary curves relative to relaxation, so that the differences which the curves indicate are probably smaller than they should be. In computing the means, the difficulty has been overcome by averaging the averages of each intensity, thereby giving equal weight to each intensity.

The frequency table follows:

the combined data of all subjects is given here (Figure VII).² This shows about the same results as the individual curves, and differs from them chiefly in its greater smoothness. It indicates the following facts:

1. There is a larger per cent of cases in the lower ranges of

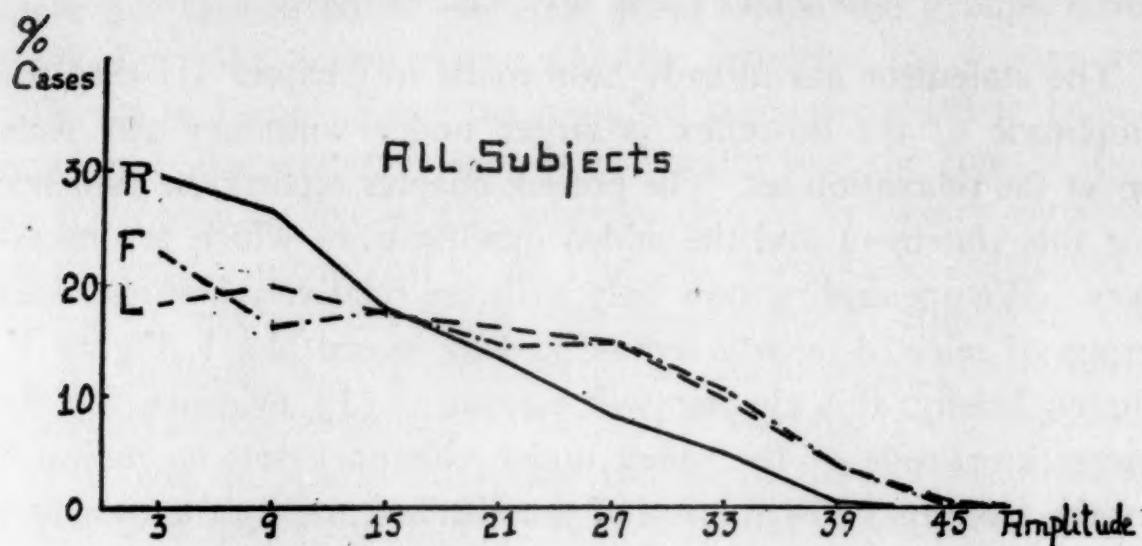


Figure VII. Distribution of Amplitudes by Sets

the distribution in the relaxation group than for either of the voluntary groups; *i.e.*, there are more small amplitudes in the relaxation group.

Frequency of Amplitude of Response by Sets

Interval Subject	Set	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48 mm.
I	R	132	69	14	11	9	5	0	0
	L	30	27	16	5	8	1	1	0
	F	80	45	27	12	7	4	1	0
II	R	33	54	35	14	13	4	0	0
	L	12	30	28	28	21	9	3	0
	F	6	19	25	19	14	9	3	0
III	R	17	12	27	27	14	6	0	0
	L	20	9	10	24	16	20	3	0
	F	28	12	34	35	27	16	4	0
IV	R	44	64	49	39	25	20	2	0
	L	45	54	42	35	32	17	15	3
	F	48	37	28	32	46	36	21	1
V	R	10	13	17	17	6	5	0	0
	L	5	3	7	18	25	11	3	0
	F	8	7	14	11	18	14	1	0

² These curves are not carried to zero because there was no case of a zero amplitude.

2. There is a larger per cent of cases in both voluntary groups above 15 mm. than in relaxation; *i.e.*, there are more cases of large amplitude in reflexes of the voluntary group.

3. For all subjects both of the voluntary curves end one step-interval above that on which the relaxation curve ends; *i.e.*, there are no cases of response during relaxation of over 42 mm. while the voluntary curves end on 48 mm. There is, consequently, a greater range of amplitude for the voluntary than for the relaxation set.

4. The voluntary curves show distributions more similar to each other than to the relaxation curve.

5. A slight tendency to bimodality appears in the voluntary curves which does not seem to be present in the relaxation curve. This is more evident in the individual curves and may be related to the close connection between facilitation and inhibition, which would lead us to expect a mixture of very large and very small responses.³

MEASURES OF CENTRAL TENDENCY

Means. Table II presents the data on amplitude of response divided by subjects, by sets within each subject, and by intensity of stimulation within each set. Averages of each of these subdivisions are given, the number of cases and the standard deviation of each average. Further, the last column, M, shows the average of the means of the four intensities for each set, for each subject. The figures under the heading, 'All Subjects', are means of each intensity for each set. In other words, we have averaged the five values for A intensity, relaxation set; the five values of A intensity, lid set, etc.; then, the five values of B intensity, relaxation set, etc. Finally, the five individual means for each set found in the last column of Table II have been averaged and these appear in the lower part of the last column of Table II. These are composite values of the three sets which include the averages of all intensities and all subjects equally weighted.

³ Golla and Antonovitch (21) observe that "isolated knee jerks may occur, during the heightened phase which are not only much smaller than their neighbors, but may actually be much less than those occurring when the tonus is depressed during the resting period".

We summarize the results of Table II:

1. *Of 40 possible points of comparison between the mean amplitudes of reflexes under relaxation and voluntary sets, 36 of these show higher amplitudes for the voluntary sets. (Only responses to corresponding intensities of stimulation are being compared.)*

2. *Set averages for each individual show in all cases that the mean amplitudes of voluntary sets exceed those of relaxation.*

3. *The composite means of all subjects show clearly larger amplitudes for both voluntary sets.*

4. *Three of the four exceptions to the stated general relationship occur in subject III, the fourth in subject IV.*

TABLE II
AMPLITUDE OF RESPONSES BY SETS, INTENSITY AND SUBJECTS
REFLEX RESPONSES IN MILLIMETERS

Subjects	Set	Intensity	A	B	C	D	M
I	R	Mean	2.6	5.8	7.2	10.7	6.6
		σ	2.5	5.3	5.9	7.1	
		N	56	59	56	61	4
	L	Mean	3.4	8.5	13.5	18.8	11.0
		σ	3.4	4.6	7.5	8.1	
		N	23	27	19	19	4
	F	Mean	3.7	8.1	9.6	16.0	9.3
		σ	3.5	9.0	7.0	7.3	
		N	47	47	43	39	4
II	R	Mean	7.4	11.3	14.7	19.0	13.1
		σ	4.9	7.1	7.7	8.6	
		N	50	47	38	18	4
	L	Mean	11.5	16.7	23.2	25.4	19.1
		σ	7.3	7.0	9.9	6.8	
		N	46	43	27	14	4
	F	Mean	12.0	17.2	23.1	30.4	20.7
		σ	6.8	9.3	7.9	5.7	
		N	37	28	23	8	4
III	R	Mean	12.4	18.9	17.5	21.9	17.7
		σ	7.6	6.9	10.6	6.4	
		N	29	26	19	18	4
	L	Mean	10.9†	19.8	20.6	29.3	20.1
		σ	9.8	11.2	10.0	6.7	
		N	28	24	22	22	4
	F	Mean	7.9†	18.3†	22.7	24.9	18.5
		σ	7.8	9.6	7.8	5.6	
		N	39	35	36	33	4

TABLE II—Continued

Subjects	Set	Intensity	A	B	C	D	M
IV	R	Mean	10.6	13.8	12.3	15.2	13.0
		σ	8.2	8.0	7.1	7.1	
		N	56	51	50	43	4
	L	Mean	10.3†	18.5	17.0	19.8	16.4
		σ	9.8	9.3	10.3	11.3	
		N	52	55	56	58	4
	F	Mean	13.5	17.3	20.1	23.2	18.5
		σ	10.5	11.8	10.9	11.8	
		N	57	53	56	55	4
V	R	Mean	11.8	16.4	20.6	19.4	17.0
		σ	7.9	6.5	7.3	8.8	
		N	25	20	11	12	4
	L	Mean	20.8	23.2	24.3	25.9	23.5
		σ	9.6	8.3	9.3	4.3	
		N	23	20	14	15	4
	F	Mean	18.7	18.3	21.8	20.8	19.9
		σ	8.1	12.6	9.8	12.2	
		N	18	25	17	13	4
All Subjects	R	Mean	8.9	13.2	14.4	17.2	13.5*
		σ	3.6	2.3	4.6	3.9	
		N	5	5	5	5	5
	L	Mean	11.4	17.3	19.7	23.8	18.0*
		σ	5.5	4.9	3.9	4.0	
		N	5	5	5	5	5
	F	Mean	11.2	15.8	19.5	23.1	17.4*
		σ	4.0	3.9	5.0	4.7	
		N	5	5	5	5	5

* These values are averages of the five values for each set in the column above.

† These are the cases in which the Mean of the relaxation set exceeds the corresponding value in either of the other two sets.

Statistical Reliability of Differences between Means

Table III contains the ratios of the differences between the mean amplitudes of sets and the standard deviations of these differences.⁴

⁴ The values of these ratios have been diminished by the classification and elimination of records, which has reduced the number of cases very much. Further, the values of σ difference could be reduced and the ratios of Table III increased if we could make use of the formula for σ difference which takes account of the correlation between series:

$$\sigma \text{ diff.} = \sqrt{\sigma^2 av_1 + \sigma^2 av_2 - 2r \sigma av_1 \sigma av_2}$$

There is clearly some correlation between the standing of the subjects on the different sets. We have not felt justified, however, in calculating correlations for such a small number of subjects.

TABLE III

STATISTICAL RELIABILITY OF AMPLITUDE DIFFERENCES BETWEEN SETS*

Intensity		A	B	C	D	Average of 4 Intensities
Sub- jects	Sets Compared					
I	Relax. & Lid	1.1	2.4	3.5	3.9	2.9
	Relax. & Finger	1.8	1.5	1.9	3.6	2.2
II	Relax. & Lid	3.2	3.6	3.8	2.4	3.2
	Relax. & Finger	3.4	2.9	4.1	4.0	3.6
III	Relax. & Lid	0.6†	0.3	0.9	3.5	1.4
	Relax. & Finger	2.4†	0.4†	1.9	1.7	1.6
IV	Relax. & Lid	0.1†	2.8	2.7	2.5	2.1
	Relax. & Finger	1.7	1.8	4.4	4.1	3.0
V	Relax. & Lid	3.5	2.9	1.1	2.4	2.5
	Relax. & Finger	2.8	0.6	0.4	0.4	1.0
All Subjects	Relax. & Lid	0.8	1.7	1.9	2.5	
	Relax. & Finger	0.9	1.3	1.6	2.1	

* This is the usual ratio of the difference between the means to the sigma of the difference $\left(\frac{D}{\sigma_d}\right)$.

† These values are the cases in which the mean of the relaxation set is greater than those of the other sets. In all other cases the means of the relaxation set are smaller.

On the usual assumption that a difference that is three or more times its standard deviation is statistically reliable, we find: (1) 13 of the 40 differences between mean amplitudes are statistically reliable; 10 are between two and three times their standard deviation; 9 are between one and two times the S.D.; and 8 are between 0.13 and 1.0 times the S.D.

(2) Of the group of smallest reliability (0 to 1.0), 3 are cases where the relaxation mean exceeds the voluntary means.

(3) The reliability of the difference between the averages of all subjects for each intensity is small because there are only five cases. The most significant facts from this part of the table are the greater reliabilities of the difference between the sets when the large intensities were stimulating, and the greater reliability of difference between relaxation and lid, than between relaxation and finger-voluntary. The first fact seems possibly explicable by the likelihood that existent differences between sets are obscured in reading the responses of small amplitude whereas in those of larger amplitude (which is equivalent to saying those in response to greater intensities of stimulation) more accurate reading is possible. The second may indicate that the set, when directed specifically to the reacting muscles, has a greater effect than when directed to remote muscles. This will be discussed later.

Medians. Table IV contains the medians for the distributions of the total number of cases for each subject, and alongside these

TABLE IV

Subjects	MEDIAN AMPLITUDES AND OVERLAPPING BY SETS				
	Relaxation	Lid-voluntary		Finger-voluntary	
		% cases exceeding		% cases exceeding	
	Medians	Medians	Relax. Median	Medians	Relax. Median
I	5.2 mm.	8.8 mm.	68.7%	6.8 mm.	60.6%
II	10.4	17.2	74.0	17.2	79.8
III	17.0	21.2	63.3	18.7	56.9
IV	13.4	15.8	56.3	20.3	63.7
V	16.1	24.7	83.3	22.5	66.3

medians is placed the per cent of responses of each voluntary set which exceeds the median amplitude of the relaxation set for that subject. The data in this table are consistent with those

of Table II. Here, however, there are no exceptions. *In all cases, the median amplitudes of both voluntary sets exceed those of the relaxation set.* Further, for all individuals the relative standing on lid and finger sets is consistent with the standing as indicated by the means.

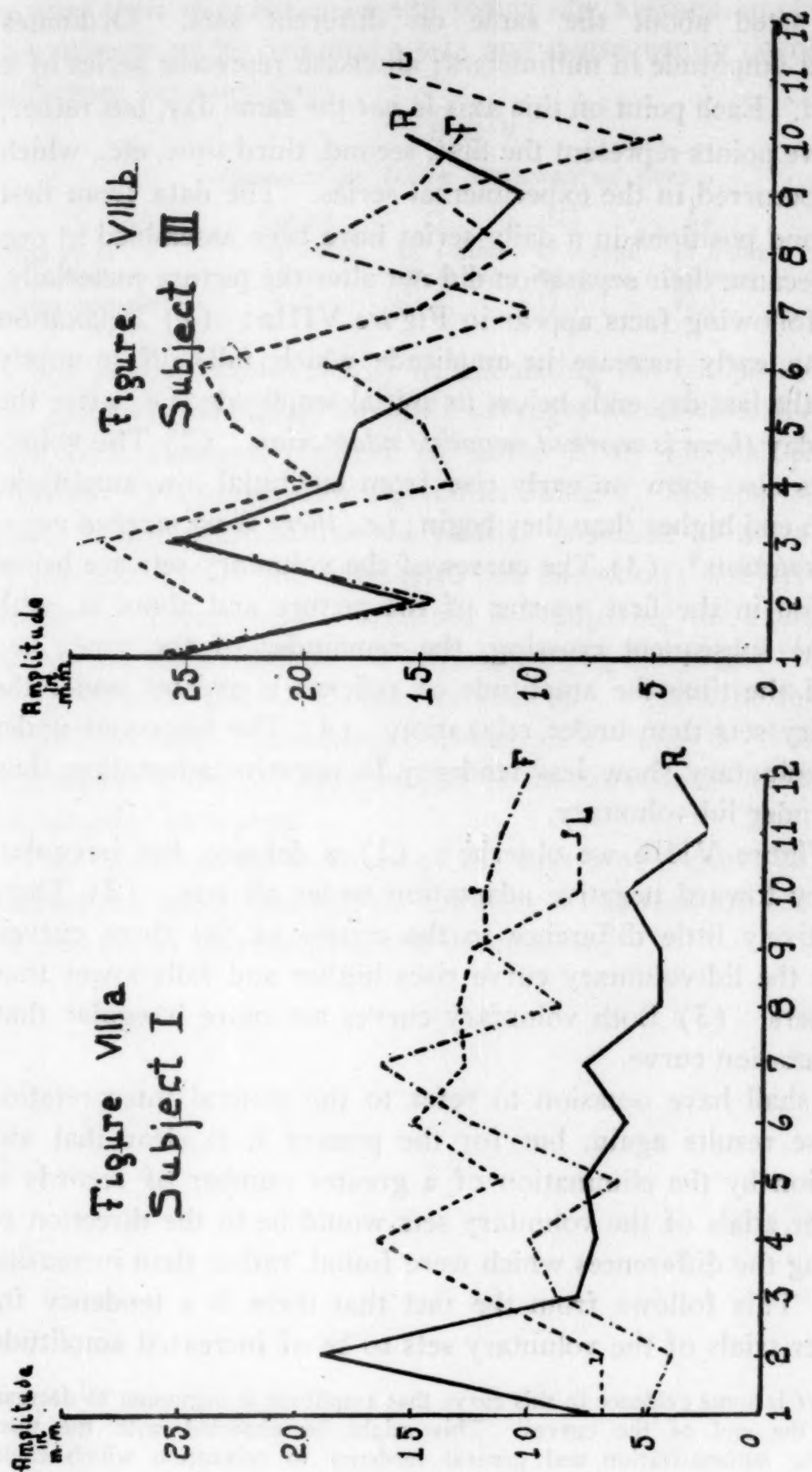
THE EFFECT OF REPETITION UNDER DIFFERENT SETS

After examination of the foregoing evidence and the rather consistent tendency for the amplitudes of reflexes under voluntary sets to exceed those under relaxation, it occurred to us that the difference might not really be a function of the set but only an accidental result of the fact that more cases had been excluded from the voluntary sets than from relaxation. Since the excluded cases, the 'modified reflexes', increased in number as the trials proceeded and since most studies⁵ have indicated a marked tendency to negative adaptation of reflexes with repetition, these later, excluded responses would presumably tend to be of increasingly small amplitudes. In this case, the elimination of records might have reduced the effect of negative adaptation in the voluntary sets more than in relaxation, so that the demonstrated differences might be due to the presence in the voluntary set data of a relatively greater number of records from the early trials and fewer from the later trials.

This possibility needed investigation. The first check is given in curves for each set showing the average amplitude on successive days of repetition. These daily averages are averages of the four intensities for each day. In some instances there were no cases for one or more intensities on a given day. If there were values for as many as three intensities, those were averaged; if less, that day was omitted and a gap was left in the curve. Small question marks are placed above the points which were determined by averages of only three intensities.

Figure VIIIa is constructed from the data on subject I and is typical of four out of the five subjects. VIIIb is a similar curve from subject III, who here, as elsewhere, shows evidence of

⁵ Dodge (11, 12); Cohen (7, 8).



Effect of Repetition

having acted about the same on different sets. Ordinates represent amplitude in millimeters; abscissae represent series of a *given set*. Each point on this axis is *not* the same day, but rather, successive points represent the first, second, third time, etc., which the set occurred in the experimental series. The data from first and second positions in a daily series have been assembled in one curve, because their separation did not alter the picture materially.

The following facts appear in Figure VIIIa: (1) Relaxation shows an early increase in amplitude which falls off promptly and on the last day ends below its initial amplitude; *i.e.*, after the second day *there is marked negative adaptation*. (2) The voluntary sets also show an early rise from an initial low amplitude, but both end higher than they begin; *i.e.*, *there is no marked negative adaptation*.⁶ (3) The curves of the voluntary sets are below relaxation in the first quarter of the picture and above it, with only one subsequent crossing, the remainder of the time; *i.e.*, most of the time the amplitude of reflexes is greater under the voluntary sets than under relaxation. (4) The responses under finger-voluntary show less tendency to negative adaptation than those under lid-voluntary.

In Figure VIIIb we observe: (1) a definite, but irregular, tendency toward negative adaptation under all sets. (2) There is relatively little difference in the course of the three curves, though the lid-voluntary curve rises higher and falls lower than the others. (3) Both voluntary curves are more irregular than the relaxation curve.

We shall have occasion to refer to the general interpretation of these results again, but for the present it is clear that any distortion by the elimination of a greater number of records in the later trials of the voluntary sets would be in the direction of reducing the differences which were found, rather than increasing them. This follows from the fact that there is a tendency for the later trials of the voluntary sets to be of increased amplitude,

⁶ There is some evidence in this curve that amplitude is beginning to decrease toward the end of the curves. This might be expected with the usual increasing automatization and general tendency to relaxation which comes with practice.

so that their elimination would reduce the average amplitude of the reflexes under voluntary sets and consequently decrease the difference between sets.

TABLE V

AVERAGES OF DAILY AVERAGES BY SETS

	Subj. I	II	III	IV	V
Relaxation	6.9 mm.	11.7 mm.	17.3 mm.	15.8 mm.	17.4 mm.
Lid-voluntary	11.4	19.4	18.4	16.2	24.7
Finger-voluntary	8.7	21.1	17.3	18.1	17.5

The second check consists in calculating the composite means for each set, averaging the daily averages to see how they compare with averages obtained in Table II by lumping all days together. These results are given in Table V. Comparison with Table II will indicate that the relative positions of the averages of the sets remain the same with one exception: subject III, in whom the three reversals occurred in comparing the averages by intensities, shows means for relaxation and for finger-voluntary of 17.29 mm. and 17.28 mm. respectively. Thus the finger set drops 0.01 mm. below relaxation instead of being 0.78 above it, as it was in Table II. For subject II the differences between sets are actually increased.

This bears out the evidence of the curves of Figure VIII, and justifies the conclusion that the differences obtained are not due to the process of classification and elimination.

V. THE RELATION BETWEEN FORM, AMPLITUDE, AND ADAPTATION OF RESPONSE

Even though the results, which have been stated, have shown considerable consistency, an examination of the exceptions greatly increases the significance of the findings. A comparison of subject III, who has departed most from the general tendency, with subjects I and II, who show the clearest differences, provides support for this statement.

Subjects I and II

(1) There is no single exception to the statement that the average amplitude of the reflex under voluntary sets is greater than under relaxation sets.

(2) The number of 'modified' responses under voluntary sets is far in excess of the number under relaxation. The *differentiation* in terms of frequency of certain forms of response *is marked*.

(3) The average statistical reliability of difference between relaxation and voluntary sets is greater for these two subjects. The ratios are 2.57 and 3.43 respectively for I and II.

(4) There is a marked difference in the direction of the adaptation curves for relaxation and voluntary sets; i.e., a tendency to negative adaptation appears under relaxation and an increase in amplitude under voluntary sets.

(5) In addition to these more accurately recorded facts, it is significant to note a few observations made during the course of the experiment from the behavior and reports of the subjects. Subjects I and II gave every

Subject III

(1) In 3 cases the average amplitude under voluntary sets is less than under relaxation; in 5 cases it is greater; i.e., *there is little difference between the two*.

(2) The number of 'modified' responses is very *nearly the same* for lid-voluntary and relaxation and actually more for finger-voluntary.

(3) The average ratio is 1.47 for this subject.

(4) The curves are not differentiated, all showing a marked amount of negative adaptation.

(5) Subject III was undisturbed by anything after the first few trials except that he complained occasionally of being irritated during relaxation by the signal to fixate. His whole attitude was progressively indifferent

Subjects I and II

evidence of having learned to relax in the apparatus. They usually became very drowsy under relaxation and subject I actually slept between trials on several occasions. Even though these subjects sometimes reported drowsiness on the voluntary sets they usually stated that they made special efforts at these times to speed up their responses.

Subject III

and he rarely took the trouble to discuss his set after the experiment was finished.

Circular argument must be avoided here. We cannot prove by the same data that the phenomena just described are criteria of differentiation between sets and that the subjects did or did not differentiate between sets. It has been shown that, in general, voluntary sets under the conditions of this experiment are related to augmentation of the average amplitude of response, a greater frequency of modified forms of response, a decrease or reversal of the tendency toward negative adaptation with repetition, and introspective reports of increased effort. When examining individual subjects, however, it has been found that some show results less strikingly different on different sets than do other subjects. Now we are pointing out only that when a subject shows less difference between sets in terms of amplitude, he also shows less in terms of effort felt, less difference in the form of response, and less difference in the course of the adaptation curves. These may or may not be criteria of the presence or absence of a set but they are apparently related to some common cause, or better they are concomitant variables, though this can be stated only in a general sense since a mathematical relationship cannot be derived from the present data.

VI. THE EFFECT OF SET ON LATENCY OF RESPONSE

THE RELATION BETWEEN LATENCY AND FORM OF RESPONSE

The data on latency of response have been handled in the same manner as the amplitude data. In the first place, the classification of records which was described in Chapter IV, has been used here, and the 'reflex' and 'modified reflex' records have been treated separately in order to determine whether these two groups show latency differences. Table VIa contains the main body of results on the latency data for reflex records; Table VIb is a similar tabulation of results of the cases eliminated, the 'modified reflex' type of responses. In each table the data are divided by subjects, by sets within each subject, and by intensity of stimulation within each set. Averages of each subdivision are given, the number of cases,¹ and the standard deviations. Further, the last column on the right shows the averages of the means of the four intensities for each set, for each subject.

Comparing each intensity in each subject and each set (58 points of comparison), we find only three exceptions to *the rule* that the average times are *shorter for the modified responses than for the reflex responses*.

According to Table VII, which contains the integers representing the statistical reliability of the differences between the mean latencies of the reflex and modified reflex records, 41 per cent of these differences between the two groups are statistically reliable; 29 per cent are between two and three times sigma difference; 22.4 per cent are between one and two; and 7 per cent are between 0.43 and one. 75 per cent of this last group are those cases where the means of the complex group are larger.

¹ The number of cases does not correspond exactly to those in the table for amplitudes since occasionally amplitude of a record was readable when time was not, due to stopping of the timer or some other accident.

TABLE VIa

LATENCY OF RESPONSE BY SETS, INTENSITY AND SUBJECTS
(REFLEX RESPONSES)

Subjects	Intensity		A	B	C	D	Mean of all Intensities
	Set						
I	R	Mean	47.2 σ	44.9 σ	45.2 σ	44.2 σ	45.4 σ
		σ	5.0	4.0	5.1	6.0	5.0
		N	52	56	50	59	
	L	Mean	48.6	46.2	45.9	47.0	46.9
		σ	4.4	4.2	2.3	4.4	3.8
		N	21	25	18	17	
	F	Mean	49.3	48.0	47.5	46.8	47.9
		σ	5.4	4.0	4.7	5.0	4.8
		N	43	39	36	34	
II	R	Mean	41.2	39.3	40.6	37.3	39.6
		σ	4.3	4.4	4.0	4.5	4.3
		N	46	45	37	19	
	L	Mean	40.1	38.1	36.6	39.0	38.5
		σ	5.1	3.1	5.5	5.2	4.7
		N	46	42	26	13	
	F	Mean	39.9	39.0	37.8	37.2	38.5
		σ	5.3	3.4	7.3	2.1	4.5
		N	34	30	19	7	
III	R	Mean	36.8	33.7	37.0	34.3	35.4
		σ	4.9	8.4	4.5	4.7	5.6
		N	31	27	25	24	
	L	Mean	42.3	40.6	38.7	37.0	39.7
		σ	4.7	2.5	4.5	3.9	3.9
		N	25	19	17	20	
	F	Mean	41.8	40.7	38.7	38.7	40.0
		σ	5.9	4.5	6.0	5.9	5.6
		N	40	37	37	40	
IV	R	Mean	39.1	38.7	39.9	37.7	38.9
		σ	7.5	4.4	3.7	4.3	5.0
		N	56	51	51	42	
	L	Mean	42.3	38.4	39.7	38.7	39.7
		σ	4.6	5.1	4.1	9.0	5.7
		N	43	45	50	52	
	F	Mean	40.3	39.5	38.9	38.1	39.2
		σ	5.6	3.8	4.2	5.8	4.9
		N	62	56	57	61	
V	R	Mean	38.9	32.8	35.0	35.2	35.
		σ	6.8	6.1	9.8	3.2	6.5
		N	26	20	12	12	
	L	Mean	36.0	37.0	36.1	35.8	36.2
		σ	6.3	6.5	4.8	4.4	5.5
		N	23	17	14	15	
	F	Mean	39.6	39.2	42.1	41.1	40.5
		σ	6.0	6.7	7.1	5.8	6.4
		N	19	22	16	13	
Average All Subjects	R		40.6	37.9	39.5	37.7	38.9
	L		41.9	40.1	39.4	39.5	40.2
	F		42.2	41.3	41.0	40.4	41.2

TABLE VIb

LATENCY OF RESPONSE BY SETS, INTENSITY AND SUBJECTS
(MODIFIED REFLEXES)

Subjects	Intensity Set	A	B	C	D	Mean of all Intensities	
I	R	Mean	43.5 σ	39.7 σ	41.5 σ	36.9 σ	40.4 σ
		σ	4.4	9.1	4.9	6.8	6.3
		N	11	8	13	7	
	L	Mean	43.8	44.5	42.0	41.0	42.8
		σ	8.1	6.6	6.8	5.9	6.8
		N	45	38	47	48	
	F	Mean	44.4	42.5	45.8	43.6	44.1
		σ	4.9	5.2	4.2	5.1	4.8
		N	20	22	32	33	
II	R	Mean	39.3	34.5	36.1	38.2	37.0
		σ	4.8	6.8	4.3	4.5	5.1
		N	14	21	28	37	
	L	Mean	34.2	34.0	35.9	36.2	35.1
		σ	6.7	2.9	6.0	4.7	5.1
		N	14	19	28	35	
	F	Mean	35.9	33.4	34.1	36.0	34.8
		σ	4.8	7.6	6.9	4.6	6.0
		N	18	26	39	51	
III	R	Mean	35.2	34.4	35.7	32.9	34.5
		σ	7.4	4.3	2.7	5.1	4.9
		N	19	27	31	28	
	L	Mean	37.8	37.0	34.0	35.5	36.1
		σ	6.7	3.3	8.1	3.2	5.3
		N	25	32	32	28	
	F	Mean	37.8	36.7	36.4	36.3	36.6
		σ	8.2	4.8	7.0	5.3	6.3
		N	27	30	29	29	
IV	R	Mean	33.2	32.6	34.0	33.6	33.3
		σ	5.7	4.1	4.2	3.5	4.4
		N	5	8	13	15	
	L	Mean	30.1	25.2		44.3	33.2
		σ	0	0		0	
		N	2	1	0	1	
	F	Mean		37.5	34.3	25.7	31.7
		σ		0.9	0	7.7	4.3
		N	0	2	1	4	
V	R	Mean	33.1	33.8	32.5	33.2	33.2
		σ	7.5	5.9	4.2	4.3	5.5
		N	8	15	22	25	
	L	Mean	32.3	33.0	30.9	33.6	32.5
		σ	6.3	4.3	4.8	2.2	4.4
		N	15	22	19	20	
	F	Mean	31.6	28.2	33.6	31.6	31.2
		σ	5.8	5.5	5.8	7.1	6.0
		N	11	11	17	13	
All Subjects Averaged	R		36.9	35.0	35.9	35.0	35.7
	L		35.6	34.7	35.7	38.1	36.1
	F		37.4	35.2	36.8	35.5	36.0

It would seem fairly clear, therefore, that in terms of latency, as well as form and amplitude, the group of modified reflex records differs from the selected reflex records. It is probable that the explanation for the shorter latencies of the modified responses lies in the presence in the group of responses which have been initiated by the set rather than by the noise stimulus, so that

TABLE VII

RELIABILITY OF DIFFERENCE BETWEEN REFLEX AND 'MODIFIED'
REFLEX LATENCIES

Subjects	Intensity Set	A	B	C	D
I	{ R	2.45	1.58	2.37	2.37
	{ L	3.00	1.25	3.49	4.39
	{ F	3.54	4.28	1.55	2.59
II	{ R	1.30	2.96	4.34	0.76*
	{ L	3.02	5.01	4.58	1.74
	{ F	2.80	3.49	1.86	1.11
III	{ R	1.02	0.43*	1.27	1.01
	{ L	2.67	4.40	2.64	1.34
	{ F	2.16	3.34	1.39	1.80
IV	{ R	2.19	3.84	4.65	3.65
	{ L	2.31	17.23	4.54
	{ F	2.53	8.27	3.14
V	{ R	1.96	0.48*	0.86	1.61
	{ L	1.75	2.16	3.04	1.10
	{ F	3.55	5.07	3.77	3.74

* 'Modified reflex' mean time longer.

they may be early voluntary responses which are superimposed on the reflex to the controlled stimulus. Undoubtedly there are also reflex responses due to unknown sources of stimulation. It is only suggested that early voluntary responses may be largely responsible for the present fact because of the relation between the complex responses and the voluntary sets.

TABLE VIII

RELIABILITY OF LATENCY DIFFERENCES BETWEEN SETS (REFLEXES)

Subjects	Intensity Set	A	B	C	D	Average
I	Relax. & Lid	1.47	1.39	0.34	2.14	1.33
	Relax. & Finger	1.94	3.73	2.11	2.25	2.50
II	Relax. & Lid	0.495*	0.69*	3.11*	1.00	1.32
	Relax. & Finger	0.57*	0.30	1.54*	0.08*	0.62
III	Relax. & Lid	4.25	2.87	1.28	2.05	2.61
	Relax. & Finger	3.83	3.97	1.29	3.26	3.08
IV	Relax. & Lid	2.52	0.32*	0.29	0.66	0.95
	Relax. & Finger	0.97	1.02	1.28	0.32	0.89
V	Relax. & Lid	1.52*	2.02	3.20	0.41	1.78
	Relax. & Finger	0.36	3.31	2.13	3.12	2.23

* Latency longer under relaxation.

RELATION BETWEEN SETS AND LATENCY OF RESPONSE

The results relative to the effect of set on the latency of response are not as consistent as those on amplitude. Two opposite tendencies are in evidence: (1) for reflex latency to be shorter under relaxation than under voluntary sets; (2) for reflex latency to be longer under relaxation sets than under voluntary. The first relationship is the more frequent, but not consistent

enough to warrant generalization without qualification. It is to be remembered that all statements are based on the treatment of the selected reflex records.

Distribution Curves

The time data, stated in terms of thousandths of a second, have been arranged in frequency tables with group intervals of two sigma, ranging from 25 to 50 sigma (all values below 25 sigma have been lumped together in one group). Figures IXa and IXb present these data for two subjects in the form of distribution curves. These subjects are the typical representatives of the two opposing tendencies. In Figure IXa there is a slight shift of the curve for relaxation to the left; *i.e.*, it shifts to the region of shorter times, while both finger- and lid-voluntary curves show tendencies to slightly longer times. In IXb the tendency is reversed. We may say, therefore, that the distribution curves indicate: (1) the subjects are divided into two groups represented by these two curves, (2) subjects I and II (who showed the most consistent and largest increase in amplitude under voluntary sets) fall into the group in which the latencies are shorter for the reflex under voluntary set than for relaxation, (3) subjects III, IV, and V fall into the other group in which there is a tendency for the latency of the reflex to be longer under voluntary sets than under relaxation. (These subjects showed less difference in amplitude of response under the different sets than the others did.)

Means. Table VIa contains the average latencies of the selected responses for each intensity of each set and subject. The following facts are indicated:

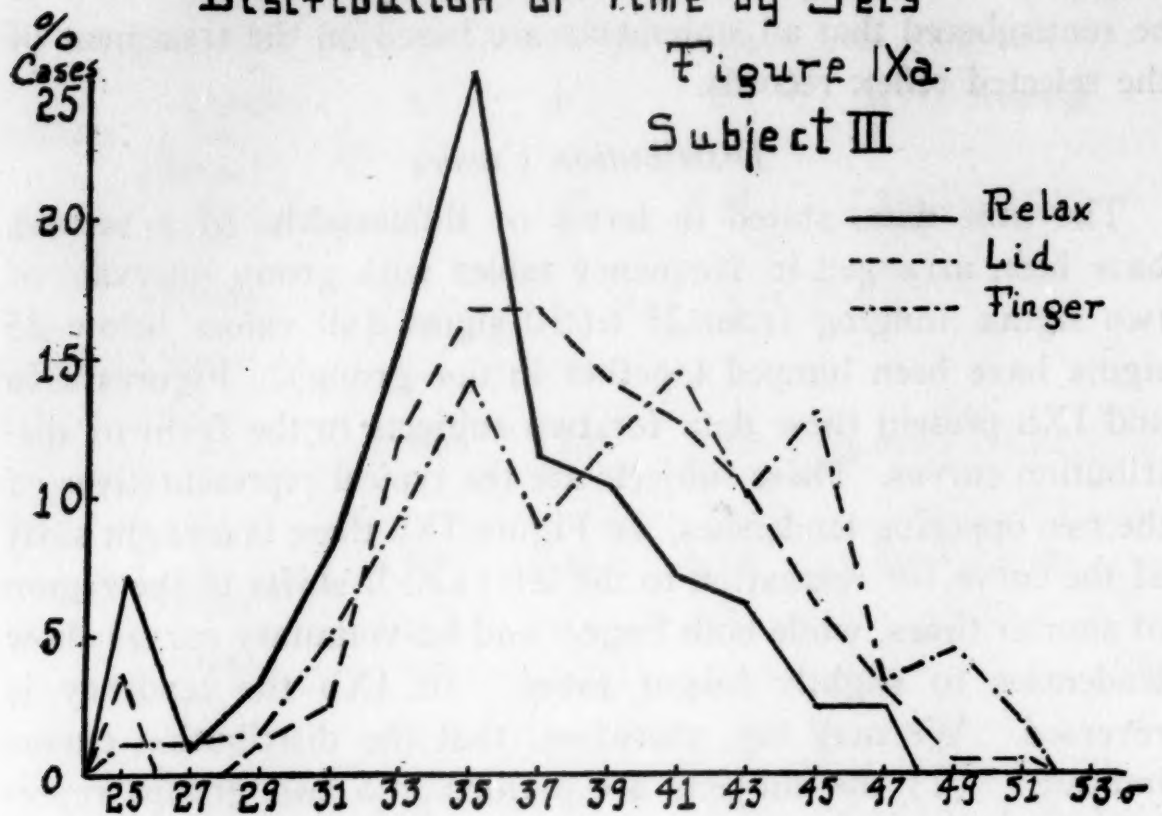
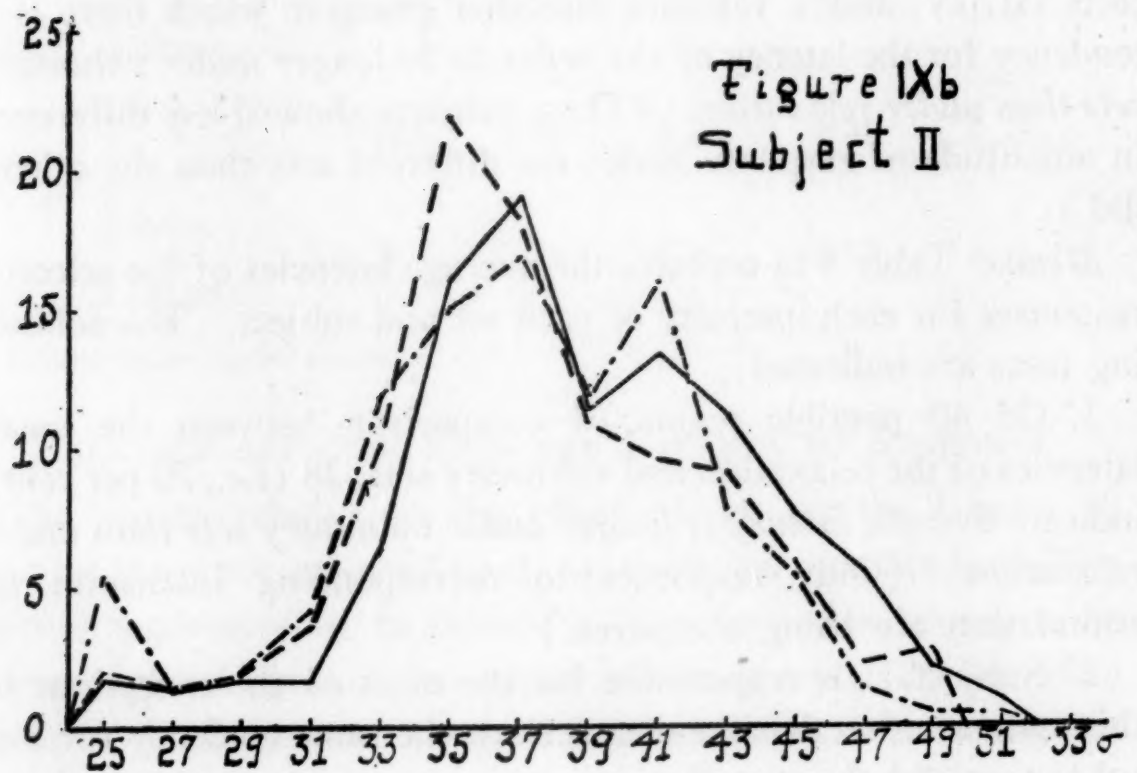
1. Of 40 possible points of comparison between the mean latencies of the relaxation and voluntary sets, 28 (*i.e.*, 70 per cent) indicate that the latency is longer under voluntary sets than under relaxation. (Only responses to corresponding intensities of stimulation are being compared.)

2. Subject II is responsible for the most of the exceptions to this statement, so that the means show the same tendency for this subject as did the distribution curves.

Distribution of Time by Sets

Figure IXa.

Subject III

Figure IXb
Subject II

3. For all subjects, save II, composite averages indicate shorter times for reflexes under relaxation than under voluntary sets, though in some cases the differences are smaller than the unit of measurement.

Statistical Reliability of Differences between Sets

The integers representing the ratio of the differences between mean latencies to the standard deviations of the differences are given in Table VIII. These, also, are small and confirm the statement that the results in this portion of the research are ambiguous. Only 22.5 per cent of these integers indicate that the difference is three or more times its sigma; 20 per cent are between two and three times sigma difference; 25 per cent between one and two; and 32 per cent between zero and one.

Medians found in Table IX bear out the results from the means, with the exception of one reversal in subject V whose median time for the lid-voluntary is less than the median time for relaxation.

TABLE IX

MEDIAN LATENCIES BY SETS

Set	Subj. I	Subj. II	Subj. III	Subj. IV	Subj. V
Relaxation	45.8 σ	38.4 σ	35.2 σ	39.0 σ	34.0 σ
Lid-voluntary	47.0	37.0	37.7	40.3	32.5
Finger-voluntary	48.2	37.2	39.5	39.5	36.0

The effect of repetition on the time of the response under different sets has been plotted, but the curves indicated no definite trends and so are not reproduced here.

VII. DISCUSSION

We have not prefaced the monograph with the usual historical introduction, reserving such references for this discussion, where their specific application will be plain. Even here the details of the experiments referred to are omitted, since many of the pertinent studies have been reviewed in Fearing's "Reflex Action" (18). We are interested chiefly in those studies which deal with the modification of relatively simple types of behavior by the general or specific background out of which they emerge. No experimental study has been discovered which attacks this problem systematically for the lid-reflex,¹ but there is a considerable literature dealing with the effects of various conditions of the organism on the tendon reflexes. It must, of course, be recognized that the situation is different for different reaction systems and that generalizations cannot be carried from one to the other. It is suggestive, however, to note the tendencies in this body of research as possible hypotheses. In the following outline a summary is given of certain experimental conditions which have been shown to affect reflex responses of the intact organism. The studies deal with tendon reflexes unless otherwise indicated. The outline does not include any of the data on modification of reaction systems by pathological conditions.

SUMMARY OF EXPERIMENTAL CONDITIONS MODIFYING REFLEX RESPONSES

I. EXTENT OF RESPONSE.

A. Inhibition produced by:

1. Voluntary contraction of extensor (in knee jerk).
 - a. Causing decreased effectiveness of stimulus.
Dodge (10).
 - b. Inhibitory effect of "cerebral innervation".
Sternberg (41).

¹ Dodge (14) has reported an experiment designed to test the 'drainage hypothesis', which bears indirectly on this problem. The subjects were set to wink arbitrarily whenever they heard the noise stimulus to the lid-reflex.

2. Reflex contraction of flexors (in knee jerk, not intact preparation). Sherrington and Liddell (29).
3. Voluntary contraction of antagonist of reflexly responding muscle. Hoffman (23).
4. Attention to the responding member, when this is a condition for the contraction of inhibiting muscles. Dodge (10), Jendrassik (25), Sternberg (41), Hoffman (23), clinicians.
5. Voluntary contraction of muscles external to specific reacting system, when this contraction is in certain temporal relations to the tendon tap. Bowditch and Warren (4), Mitchell and Lewis (53), Russetski (37).
6. Sensory stimulation when in certain temporal relations to the tendon tap. Bowditch and Warren (4), Yerkes (reflex jump in frog) (54).
7. Pain. Böhme (3).
8. Reduced tonus, relaxation. Fulton (19), Dodge (14), Jacobson (start reflex and patellar) (24), Miller (finger flexion) (34).
9. Sleep. Tuttle (49), Bowditch and Warren (4), Piéron (36), Lombard (30), Lee and Kleitman (28).
10. Warmth. Emery (15).
11. Pleasant and unpleasant affective tone. Burtt and Tuttle (6), Golla and Hettwer (22).
12. Severe exercise. Lombard (30), Brown (5).
13. Ingestion of alcohol. Dodge (lid, patellar) (13), Miles (32), Tuttle (46).
14. Repetition and refractory phase. Dodge (11), Cohen (7).

Dodge concludes (*op. cit.*, p. 120), "there was in fact no characteristic or decisive difference between the reflexes without voluntary reaction and those in which voluntary reaction occurred". This experiment was exploratory and not designed to investigate our present problem.

B. Facilitation produced by:

1. Voluntary contraction of antagonist of muscle responding reflexly. Dodge (10), Sternberg (41).
2. Pre-stimulus reflex contraction of reacting muscles. Sherrington (39, 29).
3. Voluntary contraction of reacting muscle. Hoffman (23).
4. Attention to the responding member, when not causing pre-stimulus contraction of reacting muscle. Dodge (10).
5. Attention to and voluntary contraction of muscles other than one responding to specific stimulation. This causes facilitation by:
 - a. Distracting the attention from the reflexly contracting muscle, thereby preventing its contraction prior to stimulation. Sternberg (41), Dodge (10), Jendrassik (25).
 - b. Increasing activity of the central nervous system, causing summation and spread of effects. Jacobson (24), Tuttle (47), Jendrassik (25), Lombard (30), Mitchell and Lewis (53), Bowditch and Warren (4).
 - c. Increasing tonus. Jacobson (24), Tuttle (47), Golla and Hettwer (22).
6. Sensory stimulation in certain temporal relations to reflex stimulus. This probably operates in a manner similar to No. 5. Bowditch and Warren (4), Mitchell and Lewis (53), Lombard (30), Exner (lid) (17).
7. Cold. Lombard (30), Emery (15), Miles (33).
8. Ephedrine sulphate and strychnine. Johnson and Luckhardt (27).
9. Ingestion of alcohol. Tuttle (46).
10. Increased intensity of stimulation. Lombard (30), Dodge (10), Tuttle (49), Golla and Hettwer (22).

11. "Apprehension" (lid reflex). Dodge (13), Partridge (35).
12. Hunger contractions. Johnson and Carlson (26).
13. Adrenalin (on some subjects). Tuttle (45).

II. LATENT TIME OF RESPONSE.

A. *Lengthened by:*

1. Ingestion of alcohol. Dodge (lid, patellar) (13).
2. "Relaxation." Miller (finger flexion) (34).
3. Sensory stimulation in certain temporal relations. Yerkes (flexion reflex) (54).
4. Repetition. Dodge (lid, patellar) (11).
5. Increased stature. Whitehorn and Lundholm (52), Travis (44).

B. *Shortened by:*

1. Ingestion of alcohol. Travis (42).
2. "Apprehension." Mayhew (lid reflex) (31).
"Maximum effort." Golla and Hettwer (22).
3. Stuttering. Travis (42).
4. Increased intensity of stimulation. Sherrington (39),
Fulton (19), Exner (16), Golla and Hettwer (22),
Dodge (10).
5. Sensory stimulation. Yerkes (54).
6. Tonus. Miller (34).

C. No effect (on Achilles). Tuttle (48).

1. Rate of stimulation.
2. Intensity.
3. Reinforcement.
4. Summation.

QUANTITATIVE ALTERATION OF LID-REFLEX

Augmentation of Amplitude under Voluntary Sets

It has been pointed out that the general set affects the reflex both quantitatively and qualitatively. From the quantitative point of view the set clearly modifies the amplitude of response and, with less certainty, the latency of response. Qualitatively it

is related to the form and integration of response. First, we shall discuss the quantitative modification as it is expressed in the augmentation of reflex amplitude under voluntary sets.

The fact of increased average amplitude of the reflex under voluntary sets finds corroboration in numerous studies which have indicated that increased activity of one sort or another causes a summation and spread of effect from the active member to the center controlling the reflex in question. Judging by the introspective reports of effort, by the behavioral evidence of activity, and the increased complication of response as shown on the records under voluntary sets, we are justified in assuming that in the present experiment these sets really did involve a greater amount of activity than did the relaxation set. Jacobson (24) and others have insisted that increased tonus is responsible for such effect. We have no evidence which can answer this question decisively. It seems very likely that greatly increased tonus is involved in taking a set to react voluntarily as quickly as possible, but we should like to suggest the present impossibility of determining whether such a tonic change is the cause of augmentation or the result of the same process which causes augmentation. In any case, increase in general activity, be it tonic or clonic, has been shown here and elsewhere to be correlated with an augmentation of concurrent reflexes such as the patellar reflex, lid reflex, finger flexion, etc. The explanation should presumably be sought in the concept of lowered reflex threshold produced by summation of impulses and inhibition of inhibiting processes.² To what extent facilitation is effected in the sense organs, in the central nervous system, or in the muscles, is again an important problem which cannot be answered on the basis of present evidence.

Some Conditions Where the Relation between Increased Activity and Augmented Reflex Response is Changed

In three of the subjects the relationship between voluntary set and increased amplitude was fairly consistent throughout the

² Jacobson (*op. cit.*, p. 287) summarizes the possible explanations. Fulton (*op. cit.*, Chap. XXI) elaborates the theory of the interaction in the spinal cord of inhibitory and facilitative processes from higher levels.

experiment while in two others, even though this relationship was indicated by the average and through most of the course of the curves, a significant shift in the direction of the relation occurred at the beginning of the experiment. This is evidenced in the adaptation curves of subject I, p. 31. Further, it is to be noted that the curves for all the sets reveal smaller amplitudes of the reflex in the first two practice periods than in the immediately succeeding periods. This is true of relaxation as well as the voluntary sets.

Such facts point to a relation between the initial inhibition and the degree of alertness and effort. Specifically, they suggest that in some subjects too much tension or too much effort—assuming that these are correlates of the earlier trials—can under certain conditions reduce the amplitude of response as well as increase it, and that it is only when the masking effect of this inhibition has worn off that the other relation between increased amplitude and the 'effortful' sets appears.

We have enumerated in the summary some of the conditions which have been shown to produce inhibition in other experiments. From those studies it is clear that the facilitative or inhibitory effect of concurrent activity is dependent, in the first place, on which one of two antagonistic muscles is thrown into activity by the set. For tendon reflexes Hoffman (23) and Sherrington (29) have indicated that contraction of the extensor muscle facilitates reflex contraction of the extensor. On the other hand, Dodge (10) and Sternberg (41) maintain that pre-stimulus contraction of the extensor inhibits extensor reflexes. Dodge suggests that this effect may be due largely to the fact that with mechanical stimulation of the tendon, a contracted extensor muscle actually receives less stimulation than when it is relatively relaxed. Sternberg attributes his findings to the inhibitory effect of 'cerebral innervation' which operates when the extensor is contracted voluntarily. It would not be surprising to find in the present case that as the experiment progressed, the subjects changed the relative degree of contraction of the two muscles of the lid prior to stimulation. There were, indeed, reports that the

eye was opened very widely at the beginning, but the controls did not permit our knowing how consistently this was true, so that we can draw no conclusion from the bare statement. It is only suggestive of the course which must be taken experimentally before the problem can be handled definitely.

In the second place, it has been shown that the temporal relation between various activities in the organism is a very important determinant of whether inhibition or facilitation will result from concurrent activity. Bowditch and Warren (4), for example, instructed their subjects to react to a bell signal by clenching the hand, and at varying intervals after the bell, the tendon was struck. At certain intervals between bell and tendon tap, inhibition resulted; at others, facilitation. The most interesting feature of the results, however, is the fact that on those occasions when the facilitating act actually followed the reflex response, the reinforcement was greatest. This is very much like the situation in the present experiment in which the finger response follows the reflex. In view of the evidence of a greater amount of inhibition in the finger than in the lid-voluntary set, it seems possible that some such mechanism as that of the Bowditch and Warren experiment may be operative here where there exists the possibility of changing temporal relations between the lid and finger reactions. As practice proceeds, the reaction time of the finger becomes shorter and shorter, so that a relation between the two activities, which was at first of an inhibitory nature, may become facilitative with the changes produced by repetition. This again is purely hypothetical, and suggests that more refined studies of set should somehow control the temporal relations between the activities involved.

Variability

This shift from inhibition or low amplitude to facilitation and high amplitude under the voluntary sets is consistent with other observations on the close relation of inhibition and facilitation. We have referred to the Golla and Antonovitch report (21) of the appearance of greatly augmented knee jerks in close conjunction with inhibited responses during the more tense states of the

reactor. In such a case variability is, of course, very great. In the present experiment this is indicated by the fact that the reflex amplitudes under both voluntary sets show: (1) larger standard deviation on the average; (2) a wider range of amplitude; (3) greater irregularity in the adaptation curves.

Adaptation Curves

Any explanation of why repetition may produce a different picture of change in reflex amplitude under different sets must ultimately be found in a combination of some such concepts as inhibition and facilitation as they are discussed above. Whatever the empirical facts may mean in these more theoretical terms, however, it is clear that the difference in the course of change as it has been found in this experiment must be a function of the general conditions produced by the instructions given and not of the repetition of stimuli, or the number of stimuli or the interval of time between stimuli, for all these were identical under the three sets. Furthermore, it suggests the necessity of considering the possible effect of set in all experimenting and theorizing where there is the likelihood of variation in this factor from one experimental situation to another. For example, the similarity between the 'typical' learning curve and the curve of negative adaptation in certain reflexes has been pointed to by Dodge³ as suggestive of the possibility that a common underlying process may be responsible for this similarity. The present data do not preclude this possibility but they indicate that the characteristic shape of the adaptation curve may be greatly modified by altera-

³ Dodge (12, p. 49) has made this comparison on the basis of data secured particularly from rotation experiments. In this case he does not take account of the possible effect of set on adaptation. In another connection, however, he recognizes the importance of such a factor. In "Psychological Effects of Alcohol" (13, p. 259), he reports that the extent of the lid movement decreased more than any other measured phenomena, especially in psychopathic subjects. "The general apprehensiveness of the psychopathics on their first day in the laboratory would have given us a reasonable ground for this change on the plausible, though unproved, assumption that the protective reflexes would be increased in activity if the mental 'set' were in the direction of suspicion and fear." Partridge (35) suggests a similar explanation for the diminished lid-reflex after the ingestion of alcohol, attributing it entirely to the increased indifference of the subject.

tions in set. In view of this fact, it seems likely that the curve of negative adaptation of the lid reflex must represent the composite result of adaptation of the general background of the organism, as well as an adaptation of the specific reflex in question. This being true, a distinction is called for both on theoretical and practical grounds, for it is a matter for experimental determination whether repetition produces the same rate and direction of change in the set as in the relatively circumscribed reaction system involved in the reflex. They may be the same or they may be different. Moreover, the shape of learning curve itself is undoubtedly a composite result of factors of which the set is surely one.⁴ If the similarity in curves of learning and negative adaptation is due to the presence of this common factor of a changing set, the fact is important, but it should be distinguished from the possible similarity or difference of the curves of learning and negative adaptation when set is held constant. The effectiveness of set in the two situations may be very different quantitatively with a consequent marked difference in the course of change in the two processes when this factor is not allowed to vary.

Numerous experimental results come to mind which might find applicable these facts about set. For instance, Cohen (7, p. 43) in an investigation of modification and refractory phase in the lid reflex suggests that the rate of adaptation of the reflex is a function of the time interval between paired stimuli, and he is concerned about the question of why the first of the paired responses should follow the same course of adaptation as the second even though the first of a pair succeeds the last of the preceding pair by the *same* interval in all cases. He concludes that R_1 , being in a continuous series with R_2 , is influenced by the time interval through R_2 . It would appear to be a somewhat simpler way out of the difficulty to suggest that R_1 and R_2 follow the same course of adaptation because of the same general background out of

⁴ Bills (2) has demonstrated that tension affects learning and Schlosberg (38) has shown the facilitative effect on conditioning, of voluntary reaction to the conditioned stimulus.

which both reflexes emerge and that this background changes with the progress of the experiment.

Again, Dodge (12) has observed a transfer of training from counter-clockwise to clockwise rotation in the extent of nystagmus which has first been reduced to zero for counter-clockwise rotation. Once more, might not the general background of adaptation to the situation be at least one of the 'common elements' responsible for the transfer?

In a paper to be published elsewhere we shall indicate that the set as induced by the instructions used here, may alter the size of the increments of reflex amplitude as the intensity of the stimulus is increased. This again illustrates the necessity of recognizing the possible influence of set and of controlling it. In this special case it involves the recognition that a change in a stimulus situation affects the set as well as the specific reaction system.

Such illustrations might be multiplied but it is unwarranted to stretch one type of explanation to fit too many facts. It should be pointed out, moreover, that reference to the set of the organism for a partial explanation of these phenomena really increases the number of facts to be explained. The problem of accounting for the adaptation and change of the set with repetition is no less complicated than the original problem. Even so, there is a justifiable distinction between decreased amplitude which is due to the adaptation of facilitators and a decreased amplitude which is produced by a change in a specific system mediating the reflex in question. In the first case, the response might be restored without any rest, simply by substituting a new facilitator of the same intensity; whereas in the second case, a certain period of recovery would be necessary before any facilitator of the same intensity could restore the original response.

Lid and Finger Sets Compared

(a) It has already been indicated that the amplitude of the lid reflex under the finger set shows greater extremes of facilitation and inhibition than under the lid-voluntary set. (b) It should be further noted that a small difference exists between the two in average amplitudes, though this fact should not be too much

emphasized because the differences are very small and not always consistent. On the average, however, the amplitude of the reflex under the lid-voluntary set is slightly larger than under the finger-voluntary set and the statistical reliability of difference between the lid and relaxation sets is greater than that between the finger and relaxation sets. The inference is that the locus of the activity resulting from the instructions makes a difference in its effectiveness, and that the more proximate activity has the greater effect. This question cannot be settled, however, by any experiment which does not somehow control both the intensity of the facilitating activity and its temporal relation to the reflex in question. Both these factors, as well as the locus (and other qualitative features of the activity) help determine the final result. In the present case, introspective reports indicate that the amount of tenseness developed under the finger-voluntary set was greater than that under the lid-voluntary. If this evidence can be taken as suggestive of the real state of affairs, it seems that the slightly greater facilitating effect of the lid-voluntary set, in spite of its smaller intensity, must have been due in part to the locus of the facilitating activity. (c) The tendency for the changes in the reflex under these two voluntary sets to follow so nearly the same course is, in a sense, more significant than their slight differences. That the relation of both to the relaxation set is so nearly the same for all subjects reinforces the evidence from either one of the two.

The Effect of Set on Latent Time

The extensive literature on this subject is quite as unsatisfactory as our own results. That the set affects voluntary reaction time markedly, particularly in the early stages of practice, appears to be established. On the other hand, there is disagreement among the few experiments which deal with the problem at the reflex level. Working on the lid-reflex, Mayhew (31) suggested that "in those experiments in which apprehension was felt, the average time was shorter". In 1926 Miller (34) found that the time of finger flexion to a pain stimulus was markedly increased under extreme relaxation. Golla and Hettwer (22) state "the increased knee jerk during either physical or psychical effort is

accompanied by a diminution of the latent period". In a series of 35 experiments they never failed to get this result. The shortening of the latent period amounted to as much as 4.25 sigma when the maximal effort was made.⁵

On the other hand, Tuttle (48) reports briefly and without elaboration an experiment in which clinching the hands or teeth "just before delivery of the stimulus" produced no effect on the time of the Achilles reflex. Similarly, Hoffman (23) observes "Bei ein und derselben Versuchsperson die Übertragungszeit völlig konstant ist und nicht mit der Stärke des Reizes wechselt. Bahnung und Hemmung ändern den Wert Z (time) nicht. Es mag der Erfolg noch so gering oder gross sein, immer erhalten wir die gleiche Zahl".

Our results are completely unlike those of other investigators. The suggested generalization in the present experiment in regard to the effect of set on the latency of the reflex, is that relaxation tends to shorten the latency and voluntary sets to lengthen it. Certain considerations which tend to justify such a conclusion from our apparently ambiguous data should be mentioned. It has been pointed out by Dodge and others that on mechanical⁶ records, responses of small amplitude are likely to be read at longer latencies than large amplitudes because of the difficulty of determining where the response line leaves the horizontal position. Consequently, this fact should always be taken into account when comparing latencies of responses of different amplitudes, as in the present case where set changes the amplitude of the reflex. In this experiment, however, the mechanical error of reading records could be responsible for differences which have been indicated only in the case of subject II, who showed a tendency for the latency of the lid reflex to be longer under relaxation than under voluntary sets, since the amplitude of

⁵ Fulton states (19, p. 520) that "the decerebrate jerk is actually somewhat less in latency ($1-2\sigma$) than the spinal". The fact that the decerebrate preparation shows universally greater tonus than the spinal seems to connect this finding with the present discussion. It is, however, only suggestive and indicates nothing as to what the situation might be in the intact organism.

⁶ Travis (44) has discussed the relation between amplitude and time of response in terms of possible mechanical error on action current records.

response under relaxation is smaller. In the other cases the error would have operated against the relationship indicated. This fact tends to diminish the importance of the small difference found in this subject who departed most from the conclusion suggested by the other subjects, and to indicate that the actual latency differences in the other subjects may have been somewhat obscured by such an error of reading relaxation records of small amplitude.

One possible explanation of this divergent finding occurs to us. It is well known that a set to react voluntarily with the greatest possible speed is likely to produce many anticipatory responses as well as reactions of very short latency which are really responses to the set rather than to the specified stimulus. Ordinarily there is no way of separating out these responses which do not represent the actual reaction time and in the studies indicated there were undoubtedly many of these responses under the more tense conditions, which would tend to reduce these times in a manner quite different from that implied. It has been shown that in our process of classifying records in order to obtain a homogeneous group for quantitative treatment, the selected reflexes have a longer average latent time than the excluded 'modified reflex' group. Thus it seems not unlikely that the excluded group may contain many of these very short latent times, which are voluntary responses to the set. If these had been included they would have reduced the average times of the reflexes. Since more of this group were found under voluntary sets than under relaxation the voluntary group was consequently more affected by their exclusion.

Quite irrespective of other findings, however, it is not clear why the voluntary sets should have the tendency here indicated to increase the latent time of the reflex. It can only be surmised that the sets which involve a pre-stimulus contraction of the eyelid muscles may cause a delay in the onset of the response by the conflict in the co-contraction of antagonistic muscles, the orbicularis and the levator muscles in the lid. Dodge and Bott (9) have indicated that in finger flexion a contracted muscle shows a

tendency to relax slightly before it contracts in response to a voluntary impulse. If the situation is the same for reflexes, some such mechanism might be responsible for the delay here. The point is not worth further elaboration, however, in view of the statistical unreliability of our experimental results.

QUALITATIVE MODIFICATION

Significance of the Form of Response

Our chief purpose in the procedure of analysis and classification of response forms was directed toward securing a fairly homogeneous group of responses which could legitimately be considered in quantitative terms. In addition to this point, however, certain other implications should be noted here.

It may seem to be implied from the selection of one form of response to use in our calculations that this is *the* reflex. Our meaning here should be made clear. There is obviously no basis for concluding that all lid-reflexes to sound, recorded mechanically will look like record No. 1, Figure V, or that all responses looking like this are reflexes. Further, it certainly should not be implied that any of the responses in question are the result of activity at any one level or segment of the nervous system, without intervention from others in one way or the other. It is only demonstrated that under the conditions of this experiment: (1) response No. 1 is more frequent under the relaxation set; (2) responses of short latency are more often of this form (No. 1) than those of a latency over 60 σ ; (3) the latency of certain forms decreases with repetition of the stimulus, particularly under voluntary sets; (4) the voluntary responses as seen in the second reactions of relatively long latency in the first three records of Figure VI are characteristically of much longer duration than the first reactions on these same records. In all our subjects this was true.

These empirical facts clearly suggest certain points which necessitate discussion. (1) There may be a distinction between a reflex and a voluntary response of the lid in terms of the form or integration of the response. (2) Voluntary movement, in

some cases at least, would seem to be more than an augmented reflex which Hoffmann and Fulton have suggested to be the case for tendon reactions. (3) There are certain important methodological implications from such an analysis of form.

In the first place, it is clear that the present evidence is too incomplete to establish the distinction between the reflex and the voluntary response in terms of form with any degree of generality even for the lid reaction. In the intact organism with the specific stimulating situation, the particular instructions given, and within the limits of practice here used the correlations indicated between form, set, latency and variability appear to be real. Obviously numerous variables should be investigated further to determine their effect on the integration of opening and closing: different kinds of stimuli, the instructions given, the amount of repetition, the reacting system, the voluntary response when accompanied by the reflex and when without it.

Though such an investigation would certainly be fruitful in some directions it would be surprising if this criterion of distinction between reflexes and voluntaries in terms of form did not break down at some point just as all other criteria do. The evidence indicates increasingly that behavior classifications are rarely applicable in all cases, so that here as elsewhere it is necessary to think of a given bit of behavior, not as being a reflex or a voluntary response, but as lying at empirically determined points on a number of different ordinates. So a response may be placed in terms of its latency, its time of rise to maximum, its duration, its amplitude, its inhibitability, its variability, its correlation with different sets, its threshold, etc. Then, for purely practical purposes it is convenient to speak of responses which fall predominately in one direction on the different scales as reflexes and those lying in the opposite direction as voluntary reactions. To call them one or other of these names, however, is not the problem, but rather to determine to what degree certain positions on one ordinate are related to positions on the others. Ultimately, some of the ordinates here indicated will also be analyzed further and so may be considered at any given time merely as convenient

ways of speaking about phenomena. Very occasionally one finds all-or-none characteristics which really set clear limits in classifications. The fact of the irreversibility of conduction in the reflex arc as compared with reversible direction of conduction in the nerve trunk seems to be such a one. I know of no such purely qualitative distinction between reflex and voluntary behavior, however, which would serve to make possible the classification as reflex or voluntary of any response of the lid which might be recorded. As a matter of fact the evidence suggests that the voluntary response can in many respects and under certain conditions duplicate the reflex, but that it has wider limits of variability.

It should be mentioned that Garten (26) has referred in some detail to the variation in the form of lid responses. Photographing lid movements directly on a moving film, he has observed that, "der Lidschluss durch die verschiedensten Veranlassungen in sehr verschiedener Weise erfolgt", and that the most important forms are:

"I. Längeres Zukniefen der Lider herbeigeführt durch den Willen oder durch andauernde Trigeminus oder Opticus Reizung;

"II. Kurzer Lidschluss (Lidschlag, Blinzeln) willkürlich oder durch kurze Nervenreizung herbeigeführt;

"III. Andauernder sanfter Lidschluss (Schlaf und Wille)".

He observes further, "Ausser diesen Formen des Lidschlages kommen aber, von pathologischen Erscheinungen ganz abgesehen, kurze abortive Lidschläge vor. Dieselben wurden zuerst von Fick beobachtet, die sie für von Willen abhängig hielt. Dieselben bestehen darin, dass das obere Lid gar nicht bis zum Pupillargebiet herabsinkt, sondern schon eher wiedergehoben wird."

Unfortunately Garten does not describe the experimental procedure adequately, especially the order or number of reflex and voluntary responses. It is clear that the subjects were instructed to carry out the *Lidschläge* as quickly as possible and it seems to be assumed that all responses following such instructions were voluntary. This is of course one of the criteria of distinction which we have used, but Garten's experiment does not provide

the useful check of latency of the responses. Optical, trigeminal, and corneal stimulation were used to elicit the reflex.

Several facts are evident from his investigation:

(1) The voluntary responses show a wide variation in duration of closure. Comparable figures for the reflex are not given, and no lower limit of duration for the voluntary is reported, though the curves reproduced resemble ours closely.

(2) There is a short abortive lid movement which seems to be independent of the 'will'.

(3) The duration of the stimulus affects the duration of the reflex lid closure.

(4) The velocity of closure may be the same for the reflex as for the voluntary movements, though the voluntary may be indefinitely slow.

(5) Inspection of the limited number of records which he reproduces in his article indicates that on the whole the voluntary closures, even under the instructions which he used, tend to be of longer duration than the reflexes.

These facts fit well with what we have said in regard to the probable overlapping of the reflex and voluntary response, when considered in terms of form or of any other criterion. That there are, however, certain extremes which characterize the one or the other under certain circumstances is indicated here.⁷

Granted that the form of the lid response as determined by the integration of closure and opening may fail to be a consistently applicable criterion of distinction between reflexes and voluntary responses, it is, nevertheless, important to discuss the second point

⁷ Since this was written we have discovered that Schlosberg (38) has suggested that the course of the response is different in unconditioned responses, conditioned responses, and voluntary responses. He says (p. 484), "It may be seen that the curve obtained from the conditioned reflex is very similar to that obtained during voluntary contraction of the quadriceps and quite different from the record of the unconditioned jerk. The most striking difference between these two curves and that of the unconditioned knee jerk is the sharp initial rise seen in the latter. . . . A second difference shown in the records is the greater rapidity of fall in the case of the curve of the unconditioned knee jerk, when compared with the other two records. This rapid fall, although very frequently found, is not always seen in the records of the unconditioned knee jerk."

that in some cases, at least, voluntary movement is distinguishably different from the reflex in terms of this criterion, and is more than an augmented reflex. Hoffman and Preisendörfer (23) have studied the relation of the tendon jerk to voluntary contraction and have observed that if the tendon reflexes are elicited at a high rate, a pronounced facilitation in response occurs if voluntary effort is added to the tendon response. They emphasize this very close relation between the two and suggest that under these circumstances voluntary contraction appears to be little more than a series of tendon reflexes. Fulton agrees and says (19, p. 489), "If we adopt Hoffmann's conception, voluntary contraction may in fact consist almost entirely in the release of the lower motor neurones from higher inhibitory control." We agree to the suggestion of the augmentatory effect of voluntary activity—that is indicated in the present research—but we believe that this is not the whole story of voluntary contraction as Hoffmann occasionally seems to imply. There are clearly some voluntary responses which have the appearance of being definitely more than augmented reflexes, in our sense of the term reflex.⁸ There are voluntary responses dependent on intent that really look different from the reflex, and there are the apparent combinations, especially type No. 2 responses, where it is misleading and inaccurate to describe the reaction simply as an augmented reflex. Fulton seems to recognize this fact when he says (*op. cit.*, p. 489), "It may be emphasized, however, that the motor cortex is also capable of exciting the anterior horn cells *de novo*", but he pro-

⁸ We are, of course, referring to a reflex in the intact organism. We are aware that the course of the curve of the reflex as we have found it is not the same as that of a tendon reflex in decerebrate or spinal preparations, or again, the motor twitch of muscle. The work of Ballif, Fulton, and Liddell (1) and others on the characteristics of decerebrate and spinal knee jerks and motor twitches suggests itself as related, but the neural levels, and the muscular systems, as well as the recording techniques involved are so different that it does not seem advisable to elaborate possible implications now. Similarly, Walshe's discussion (51) of the rapid and complete relaxation of the quadriceps following a knee jerk in certain spinal and cerebellar injuries as compared with the slow relaxation and sustained contraction of the normal are suggestive, but again the comparison must not be pressed too far.

ceeds to state that this class of voluntary excitatory impulses is relatively unimportant.

This brings us back to our treatment of the effects of voluntary activity on the reflex in terms of quantitative and qualitative changes. It is not unlikely that the quantitative change in the amplitude of the reflex may be produced by the relatively persistent voluntary activity released by the set. This may take effect by increasing tonus, thus indirectly lowering the threshold for the reflex, or it may act directly on the final common path to the involved muscles releasing them from higher inhibitory control. The presumption is in either case that the voluntary impulses have operated simply to clear the way for the reflex. On the other hand, in those responses which involve a breaking up of what seems to be an established reflex coördination between closing and opening of the lid, there is clearly something more than mere augmentation, and conjecturally this may be thought of as representing the clonic voluntary reaction resulting from direct excitation of the final common path. We are aware that no far-reaching conclusions can be deduced for one system from data referring to another system. The facts must be established independently for the lid reflex. The comparisons are only suggestive.

The third point refers to methodology. In the interest of establishing accurate quantitative statements of relations between various functions of the kind here studied, it is important that a technique be employed which will make possible the analysis of the response in terms of duration as well as latency and amplitude.⁹ This means that a record on a slowly moving kymograph such as has been used very often in studies of augmentation and inhibition of amplitude, must obscure important results of a qualitative kind and will at the same time make ambiguous the

⁹ Of course, an even more satisfactory technique is one which will make possible recording of the behavior of the separate muscles involved. As we have pointed out in the present case, our record is obviously the composite result of a number of factors.

quantitative results by including amplitudes of irrelevant responses. In the present case, for instance, had we included the amplitude of all our records in calculating the results, the differences of amplitudes on different sets would have been enormously increased, for the amplitudes of the 'modified' responses, which presumably involve superimposed voluntary responses, are consistently large and would have made average amplitudes on voluntary sets much larger. The determination of quantitative relationships under such conditions is quite impossible. The same criticism applies to action current records, where it is impossible to determine anything about the course of the mechanical response. The two forms of record should supplement each other for the sake of completeness.

A similar remark may be made in regard to studies involving time measures. The action current techniques clearly give a more accurate picture of the beginning of response without introducing the errors due to the slow rise of the mechanical record. On the other hand, a mechanical record has a certain advantage. We have found significant differences in the average latencies in the two groups of records, that including type No. 1 responses and that including the complex responses. The latter group shows the shorter latency. It has been suggested that by eliminating records which show irregularities and forms similar to the voluntary, we have very likely eliminated some of the reactions which were accidental or which were evoked by the set, rather than by the specified stimulus. If this is true, the process of classification has served to refine the time data by eliminating some of the irrelevant records.

SUMMARY AND CONCLUSIONS

The present investigation has attempted to discover the extent of modification produced in the lid-reflex by three different "sets" induced in the subject by instructions. The instructions were designed to establish: (1) a relaxation state; (2) a set to wink voluntarily to a loud snap which also caused the reflex wink; (3) a set to react voluntarily with the finger to the snap which

caused the reflex wink. From data on five subjects we have made the following observations:

I. The set under which the lid-reflex occurs tends to alter the reflex qualitatively:

1. A certain regular response of short latency, prompt rise to maximum, and prompt onset of opening occurred much more frequently under relaxation, and selection of this form of response from all sets was made for the purpose of obtaining a homogeneous group of records for quantitative treatment.
2. Voluntary sets appeared to modify this integration in the direction of greater duration of closure and irregularity of response. This suggests that the form of integration of the response may under certain experimental conditions differentiate reflex and voluntary responses.

II. The set under which the lid-reflex occurs tends to alter the reflex quantitatively:

A. Amplitude.

1. The average amplitude of the lid-reflex under the relaxation set is less than under either voluntary set.
2. Exceptions to this relation occur in the early trials of the series for two subjects, indicating presumably that too much effort may be inhibitory. In other words, the *amount of concurrent activity* is a factor to be considered in studying facilitation and inhibition of reflexes.
3. Comparison of the amplitudes of the reflex under the lid and finger reaction sets indicates: (a) greater variability of the finger set with the possibility that the change in temporal relation between the lid and finger reaction may be responsible for the shift from very high to very low amplitude. (b) The slightly greater amplitude of the reactions

under the lid-set suggests that the degree of proximity of activity, constituting the set, affects the degree of facilitation. Thus the *locus*, the *intensity*, and the *temporal relation* of the concurrent activity and the reflex are important factors in determining the amount and direction of modification of the reflex.

4. The effect of repetition on the amplitude of the lid-reflex may be altered with a change in set. Relaxation appears to be related to negative adaptation, and the voluntary sets to facilitation and a delay in the appearance of the process of negative adaptation.

B. Variability. Voluntary sets increase the variability in the amplitude of response. There is a close relation between inhibition and facilitation.

C. Time. The results here are not consistent, but there is some indication that the latent time of the reflex is slightly longer under the voluntary sets than under relaxation.

III. Certain methodological implications follow from these results.

1. Form analysis.

- a. The only satisfactory techniques for studying the augmentation of response under various conditions of the organism are those making possible a qualitative analysis of the responses which are to be compared quantitatively, so that the error of counting a superimposed voluntary response as an augmented reflex may not be made.
- b. In studies of time of response, also, this analysis of form seems to be important, for the 'modified' group of responses has been shown to have a shorter average latency than the selected 'reflex' group. This may indicate that the first

group contained some very short responses which were released by the set rather than by the specified stimulus.

2. The fact that the set affects the amplitude of the reflex makes necessary its control in every experiment where it may vary. Inferences from the similarity of 'typical curves' of negative adaptation and learning must consider this as a factor contributing to the shape of the 'typical' curve. Adaptation of a highly simplified response system (the reflex) must be differentiated from the adaptation of a general background, which may show a different rate of adaptation.

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For the purpose of the present investigation, the following

series of experiments were conducted, the results of which

are given in the following table.

The first series of experiments was conducted with the

view of determining the effect of the temperature of the

medium on the rate of the reaction.

The second series of experiments was conducted with the

view of determining the effect of the concentration of the

reactants on the rate of the reaction.

The third series of experiments was conducted with the

view of determining the effect of the catalyst on the rate

of the reaction.

The fourth series of experiments was conducted with the

view of determining the effect of the solvent on the rate

of the reaction.

The fifth series of experiments was conducted with the

view of determining the effect of the pressure on the rate

of the reaction.

The sixth series of experiments was conducted with the

view of determining the effect of the time on the rate

of the reaction.

The seventh series of experiments was conducted with the

view of determining the effect of the nature of the

reactants on the rate of the reaction.

The eighth series of experiments was conducted with the

view of determining the effect of the nature of the

solvent on the rate of the reaction.

The ninth series of experiments was conducted with the

view of determining the effect of the nature of the